Marine Fisheries
REVIEW
Vol. 71, No. 2
2009
United States Department of Commerce

# *Pacific Ocean Shrimp*

# Marine Fisheries REVIEW

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On the cover: Commercial fishing vessel pulling double-rig trawl gear to catch Pacific ocean shrimp, *Pandalus jordani*, or pink shrimp, in the Pacific Ocean off the U.S. west coast, Oregon. Photograph by Scott Groth, ODFW.

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The *Marine Fisheries Review* (ISSN 0090-1830) is published quarterly by the Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., BIN C15700, Seattle, WA 98115. Annual subscriptions are sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. The annual subscription price is $21.00 domestic, $29.40 foreign. Single copies are $12.00 domestic, $16.80 foreign. For new subscriptions write: New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954.

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This publication is available online at http://spo.nwr.noaa.gov/mcontent.htm

# Review of the California Trawl Fishery for Pacific Ocean Shrimp, *Pandalus jordani*, from 1992 to 2007

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## Introduction

The Pacific ocean shrimp, *Pandalus jordani*, usually referred to as pink shrimp, is a commercially important pandalid shrimp species harvested with bottom-trawl gear off the Pacific coast of the United States and Canada. They are sold as cocktail or salad shrimp, after being machine cooked, peeled, and frozen (Fig. 1). The pink shrimp trawl fishery has been an important component of many coastal community economies in California for over 50 years, although production has decreased sharply in recent years.

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*ABSTRACT—The commercial bottom trawl fishery for Pacific ocean shrimp,* Pandalus jordani, *or pink shrimp, operates mostly off the west coast of the contiguous United States. The California portion of the fishery has not been thoroughly documented or reviewed since the 1991 fishing season, despite its fluctuating more during the last 16 years (1992–2007) than at any other period in its 56-year history. We used fishery-dependent data, California Department of Fish and Game commercial landing receipts and logbook data, to analyze trends and review the California pink shrimp trawl fishery from 1992 to 2007. In particular, we focus on the most recent years of the fishery (2001–07) to highlight the gear developments and key management measures implemented in the fishery. The fishery is primarily driven by market conditions and is highly regulated by both state and Federal management agencies. Several key regulatory measures implemented during this decade have had significant effects on the fishery. For example, the requirement of a Bycatch Reduction Device on trawl nets targeting pink shrimp was approved in 2001 and has greatly reduced levels of finfish bycatch. Fishery production has declined, particularly in recent years, and may be attributed to decreased market prices, followed by reduced fishermen participation; both of which are related to changes in the processing sector and demand for the product.*

The pink shrimp fishery operating in ocean waters off California is managed by the California Department of Fish and Game (CDFG), under the California Fish and Game Commission (CFGC). However, because groundfish are taken as bycatch in this fishery, it is considered a non-groundfish trawl fishery under the U.S. Pacific Groundfish Fishery Management Plan. The Federal management regulations for this fishery include groundfish trip limits, seasons, gear restrictions, and area restrictions protecting groundfish Essential Fish Habitat (Code of Federal Regulations, 2008). Historically, the CDFG conducted research on the pink shrimp fishery, including cruise surveys, development of population models, and a dockside biological market sampling program. The CDFG cruise surveys were used to estimate shrimp population sizes, mortality rates, and growth rates from 1959 to 1968, but they were discontinued because they were too expensive (Gotshall, 1972; PFMC[1]).

Population models were developed by CDFG statisticians to estimate recruitment, spawning stock abundance, and set the catch quotas from 1969 to 1976. However, the models were subsequently dropped because the exploitation rate for age-1 shrimp, which typically constitute most of the spawning stock, was determined to be low and therefore able to be managed without a quota (Geibel and Heimann, 1976; PFMC[1]). Population models were also found to have inaccuracies due to the variable recruitment, growth, and natural mortality rates associated with pink shrimp (Hannah, 1999). The dockside biological market sampling program provided data on pink shrimp size, sex, age composition, and the count-per-pound, but this program ceased in 1992 due to a lack of available staff and resources.

Essential fishery information on the California pink shrimp fishery was consistently collected from the 1960's through the 1980's. In addition, a fishery management plan was drafted for the pink shrimp fishery off Washington, Oregon, and California in 1981 because of concerns about an increase in fishing effort coupled with a coastwide decline in catch per unit of effort (CPUE) for pink shrimp (PFMC[1]). However, the Pacific Fishery Management Council (PFMC) did not adopt the plan and deferred management of the fishery to

[1]PFMC. 1981. Discussion draft fishery management plan for the pink shrimp fishery off Washington, Oregon and California. Pac. Fish. Manage. Counc., Portland, Oreg., 169 p.

the U.S. west coast states which had historically worked collaboratively to minimize interstate conflicts and resource issues (PFMC[1]; MSC[2]).

Reports on the trends and status of the California pink shrimp fishery were also published on nearly an annual basis by CDFG from 1959 to 1992 and California Cooperative Oceanic Fisheries Investigations Reports from 1984 to 1992. The Pacific States Marine Fisheries Commission (PSMFC) published just six brief summaries of the California pink shrimp fishery (1992–95; 1999–2000). Aside from these six brief PSMFC annual summaries, only two status reports or other published documents have been written on the California pink shrimp fishery since the 1991 fishing season (Collier and Hannah, 2001; Frimodig et al., 2008). Since 1992, there have been extreme fluctuations in annual landings, as well as innovative gear developments and key management measures implemented; all have had substantial impacts on the current fishery. Therefore, the objective of this paper is to analyze trends and review the California pink shrimp trawl fishery during the 16-year period from 1992 to 2007, with an emphasis on the most recent years of the fishery.

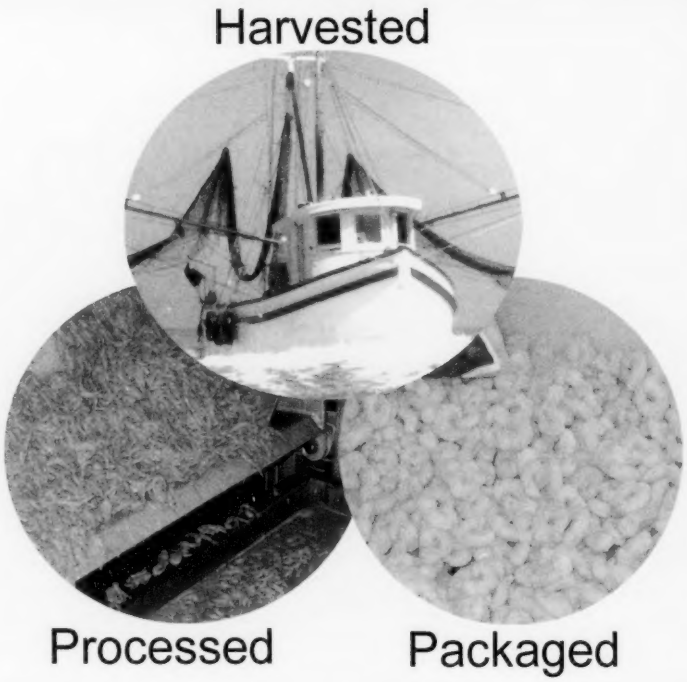


Figure 1.—Pink shrimp are harvested off the Pacific coast of the U.S., cooked, peeled and processed, and sold as salad shrimp, or cocktail shrimp. Credit: Pink shrimp photographs were taken by Adam Frimodig, CDFG, courtesy of Pacific Choice Seafoods; vessel photograph was taken by NOAA.

## Biological Characteristics

Pink shrimp range from the Aleutian Islands in Alaska to San Diego, California, and the center of distribution occurs off the Oregon coast (Dahlstrom, 1970; PFMC[1]). Commercial quantities are generally confined each year to well-defined locations, or beds, from Queen Charlotte Sound, British Columbia, to Point Arguello, California (Dahlstrom, 1970; PFMC[1]). Off the California coast, pink shrimp are most abundant in the same general beds from year to year (Fig 2). These beds are primarily soft-bottom habitats characterized by green mud or muddy-sand at depths between 90 and 200 m (Dahlstrom, 1970; Bergstrom, 2000; PFMC[1]).

From 2000 to 2007, logbook data for all trips targeting pink shrimp off California indicate that the average fishing depth was 158 m, and ranged from 47 to 360 m. The largest bed extends from the Eureka area to the Oregon border. Several beds are located between False Cape and Point Reyes, and another bed is found near Morro Bay (Fig. 2). Commercial quantities of pink shrimp also occur infrequently in the Santa Barbara Channel between Point Conception and Pitas Point (Fig. 2).

Pink shrimp are protandric hermaphrodites, generally functioning as males for the first year and a half of their life before developing into terminal females (Butler, 1964), although the age at which individuals change sex can vary from year to year in response to the population structure (Hannah and Jones, 1991; Charnov and Hannah, 2002). Spawning typically takes place during September and October (Dahlstrom, 1970). Pandalid shrimp have external fertilization, and females carry fertilized eggs on their pleopods until they hatch (Balsiger, 1981; PFMC[1]). The peak hatching period for pink shrimp occurs between late March and early April (Butler, 1964; Dahlstrom, 1970). Newly hatched larvae pass through a planktonic phase which lasts approximately 4 months from late winter to July, and the developing juvenile shrimp inhabit successively deeper waters as they grow. They usually turn up in commercial catches by late summer (Dahlstrom, 1970; Rothlisberg and Miller, 1983; PFMC[1]). Growth rates, typically highest during the spring and summer, vary by region, sex, age, and year class (Dahlstrom, 1970; Gotshall, 1972).

Pink shrimp undergo a diel migration pattern moving between a deeper, northward flowing undercurrent during

[2]MSC. 2007. The Oregon pink (ocean) shrimp trawl fishery. Mar. Stewardship Counc., London, U.K., Final Rep. Version 3, 137 p. (online at http://www.msc.org/assets/docs/Oregon_pink_shrimp/Final_Report_Oct_2007.pdf).

the day to a generally southward, surface moving current during the night (Pearcy, 1970; 1972). Some horizontal, onshore-offshore transport may occur within the confines of a single bed due to prevailing currents and feeding activity. Planktonic larvae may be carried long distances, but no convincing evidence suggests pink shrimp exhibit large coastwide migratory behavior (Dahlstrom, 1970; Pearcy, 1970; Rothlisberg and Miller, 1983).

Pink shrimp are an important component of the food web in the northeast Pacific Ocean (Field et al., 2006). They feed primarily at night, ascending in the water column to locate smaller planktonic crustaceans, such as euphasiids and copepods (Pearcy, 1970; Gotshall, 1972). The vertical migration of pink shrimp may also reduce their susceptibility to visual predators during the night (Pearcy, 1970). Pink shrimp are preyed upon by mostly groundfishes, such as Pacific hake, *Merluccius productus*; arrowtooth flounder, *Atheresthes stomias*; sablefish, *Anoplopoma fimbria*; petrale sole, *Eopsetta jordani*; spiny dogfish, *Squalus acanthias*; and several species of rockfishes, *Sebastes* sp., and skates, *Raja* sp. (Gotshall, 1969; Dahlstrom, 1970; Hannah, 1995). Natural mortality rates vary considerably from year to year and have been linked to the abundance of Pacific hake (Hannah, 1995).

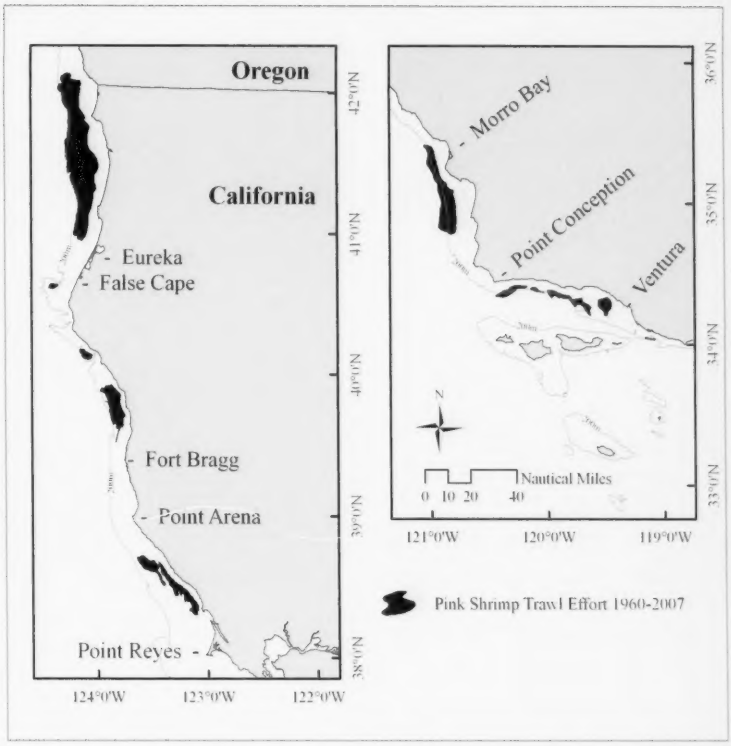


Figure 2.—Historical pink shrimp trawl effort from 1960 to 2007 showing the main pink shrimp beds off the coast of California. Source: CDFG historical Annual Ocean Shrimp Reports (i.e. Administrative Reports) and CDFG pink shrimp logbook data.

In the last 3 years, the age composition of pink shrimp harvested off the Oregon coast has fluctuated greatly. The age-1 year class was strong in 2005, weak in 2006, and strong again in 2007, constituting 85%, 15%, and 83% respectively of the catch (ODFW[3]). Age-1 shrimp generally range from 13 to 17 mm, age-2 range from 18 to 25 mm, and age-3 from 25 to 29 mm (Fig. 3) (Dahlstrom, 1970).

Short-lived invertebrates, such as pandalid shrimp and market squid, *Loligo opalescens*, tend to exhibit large natural fluctuations in abundance, yet the fisheries targeting these invertebrates appear to be sustainably managed with relatively minimal regulatory actions (Field and Francis, 2006). However, changes in growth, age, and sex composition of the pink shrimp catch have been partly attributed to the trawl fishery. Hannah and Jones (1991) found that when the catch of age-3 pink shrimp decreased, the catch of age-1 shrimp increased, and the percentage of age-1 shrimp transitioning from males to females increased concurrently with a reduction in CPUE.

Despite the potential fishing effects on the population, pink shrimp are short-lived, may exhibit density-dependent growth patterns, and their abundance appears to be primarily influenced by environmental factors (Hannah and Jones, 1991; Hannah, 1993; 1999; Perry et al., 2000). Annual recruitment success has been linked to the strength and timing of the "spring transition," which is the most critical period for seasonal plankton production cycles and refers to the seasonal change in wind patterns that force a shift in coastal currents from a winter downwelling condition to a summer upwelling condition. An early, strong transition is necessary to produce a large year class (Hannah, 1993; 1999). This suggests fishing pressure may have relatively little effect on stock status, although overfishing may be possible if intensive fishing occurs on a failed year class.

## History of the Fishery

The commercial trawl fishery for pink shrimp began in 1952 off Morro Bay, California, after commercial concentrations were found in 1950 and 1951 by CDFG research vessels (Dahlstrom, 1961). The pink shrimp fishery expanded in California off Bodega Bay, Fort Bragg, Eureka, and Crescent City, and northward to Oregon and Washington

[3]ODFW. 2008. 19th Annual pink shrimp review. Oreg. Dep. Fish Wildl., Mar. Resour. Program, Newport, Oreg., 8 p. (online at http://www.dfw.state.or.us/mrp/publications).

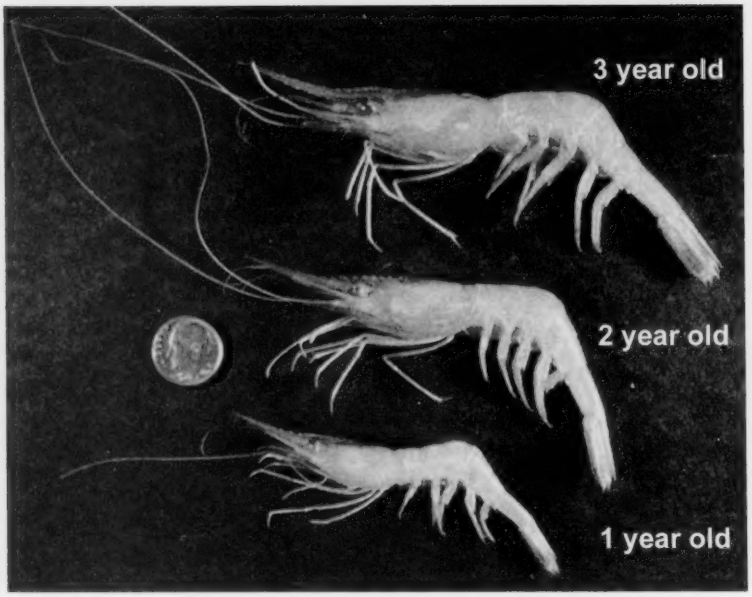


Figure 3.—Three size (age) classes of Pacific ocean shrimp, *Pandalus jordani*. Credit: Robert W. Hannah, ODFW.

in the mid to late 1950's (Dahlstrom, 1973). The CFGC designated three regulatory areas for the harvest of pink shrimp in 1952 (Areas A, B, and C), which encompassed both state and Federal waters adjacent to California.

The CFGC first established regulations for the fishery in 1952 including the use and submittal of logs to document catch and effort, gear restrictions, open and closed seasons, and annual catch quotas. Fishermen were limited to the use of beam trawls with a minimum net mesh size of 38 mm from 1952 to 1963, and trawling in state waters was prohibited in 1953. In 1963, fishermen were allowed to use otter trawl nets with the 38 mm net mesh size. After 1963, beam trawls were phased out and otter trawl gear became the primary gear used. All vessels in California pulled a single rig of one net and two doors prior to the 1974 season, when vessels towing a double rig (one net deployed on each side of the vessel) entered the fishery (Collier and Hannah, 2001).

Catch quotas governed landings in each regulatory area from 1952 to 1976. The quota system was abandoned in 1976, and the following regulations were enacted in an effort to protect the resource for long-term sustainability: 1) season closure from 1 Nov. through 14 Apr. to protect egg-bearing females, 2) minimum net mesh size of 35 mm to allow for escapement of small zero age shrimp, 3) maximum count-per-pound of 170 or less intended to protect 1-year-old shrimp, and 4) minimum catch rate of 350 pounds-per-hour to protect shrimp when the population was at a low level. Consistent coastwide management measures were established in 1981 based on an agreement with the Oregon Department of Fish and Wildlife (ODFW) and the Washington Department of Fish and Wildlife (WDFW). The resulting regulations, which remain in effect, include an open season from 1 Apr. through 31 Oct. and a maximum count-per-pound of 160. In California, there is an additional requirement of a minimum net mesh size of 35 mm.

Since 2000, three additional regulatory measures have been implemented in the California pink shrimp fishery. First, regulations mandating the use of Bycatch Reduction Devices (BRD's) in the U.S. west coast pink shrimp fishery were adopted in 2000 after the PFMC determined that canary rockfish, *Sebastes pinniger*, were overfished (PFMC[4]). In California, the requirement of a BRD on trawl nets used in the pink shrimp fishery was approved by the CFGC in 2001 and implemented in 2002. Three types of BRD's currently satisfy the requirement for this device in the California fishery: the Nordmøre grate (rigid-grate excluder) (Fig. 4), soft-panel excluder (Fig. 5), and fisheye excluder (Fig. 6) (California Code of Regulations, 2008a).

Second, the management of pink shrimp harvest in California was changed in 2001 from the three management regions (A, B, and C) used historically to two management regions (northern region and southern region). The northern region is a limited entry fishery extending from the California–Oregon border to Point Conception (California Code of Regulations, 2008a). The permit required for fishing in the northern region may be transferable or nontransferable. Permit transferability is limited to the transfer of a vessel permit to a replacement vessel that is no more than 5 feet longer than the original permitted vessel under the same ownership, or the transfer of a permit to an heir upon death of the permit holder. The southern region is an open access fishery extending from Point Conception to the California–Mexico border (California Code of Regulations, 2008a). Permits are required in the southern region, but there is no limit to the number that can be issued.

The third recent regulatory change in the California pink shrimp fishery occurred in 2004 when new and amended statutes granted the CFGC management authority over all state-managed bottom trawl fisheries not managed under a Federal or state fishery management plan, and prohibited pink shrimp bottom trawling in state waters after 1

[4]PFMC. 2000. Status of the Pacific Coast groundfish fishery through 2000 and recommended biological catches for 2001: stock assessment and fishery evaluation. Doc. prep. for the council and its advisory entities. Pac. Fish. Manage. Counc., Portland, Oreg.

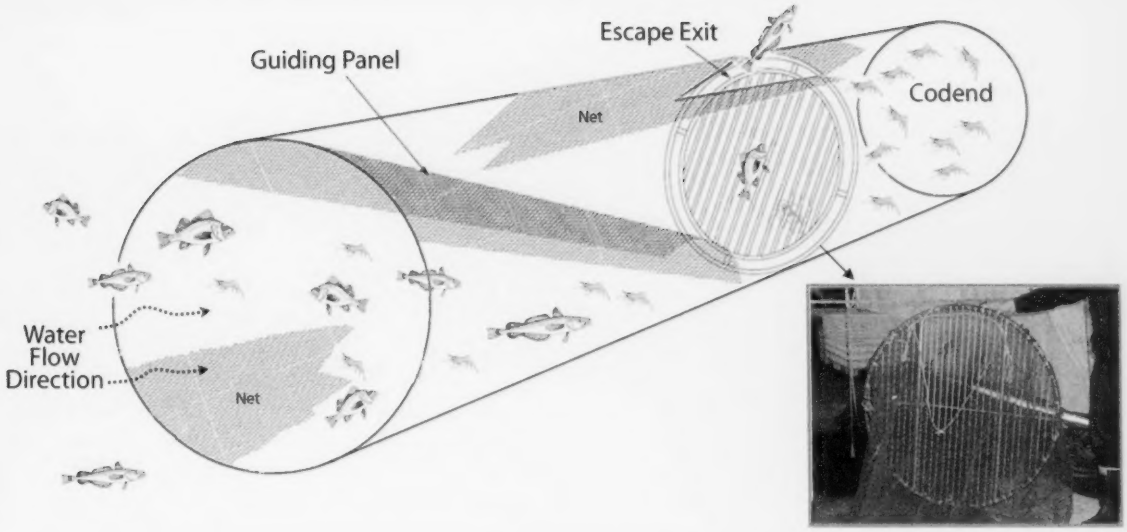


Figure 4.—Diagram of a typical rigid-grate excluder. The diagram shows shrimp traveling through the BRD, while larger fish species are deflected by the BRD and guided through the escape opening. The inset picture is a rigid-grate excluder with 32 mm bar spacing. Credit: Adam Frimodig, CDFG; diagram and inset picture modified from Robert W. Hannah, ODFW.

Jan. 2008 (California Fish and Game Code, 2008a). Prior to that date, bottom trawling for pink shrimp was authorized in state waters between 2 and 3 n.mi. (3.7 and 5.6 km) from the mainland on the north coast of California from Point Reyes to False Cape.

This portion of state waters, often referred to as the "pink shrimp trawl grounds," was the only area open to pink shrimp fishing in state waters. According to logbook data, an average of 21% of annual pink shrimp landings statewide were taken from within state waters from 2000 to 2007. The CFGC has the authority to open any state waters for bottom trawls if it determines that bottom trawling in those areas is sustainable, does not harm benthic habitat, and does not unreasonably conflict with other users (California Fish and Game Code, 2008b).

Bottom fishing gear types, such as trawling, have been considered one of the foremost global anthropogenic sources of disturbance to hard-bottom benthic communities (Auster and Langton, 1999; Turner et al., 1999; NRC, 2002). However, the effects of bottom trawling on soft-bottom habitats are

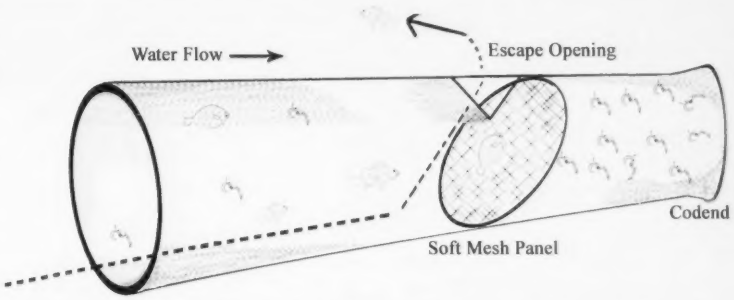


Figure 5.—Diagram of a typical soft-panel excluder. The soft-panel excluder works similarly to rigid-grate excluder, but the device is made of soft mesh rather than aluminum. Credit: Brian Owens, CDFG.

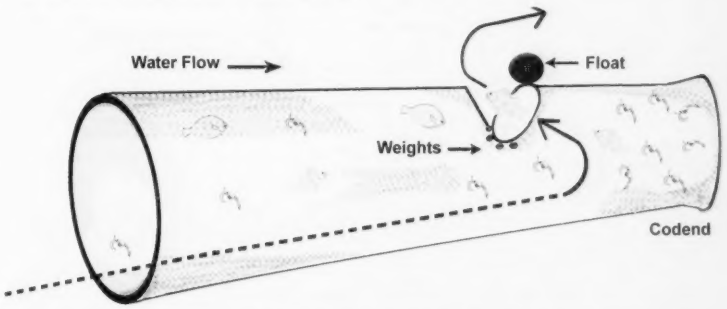


Figure 6.—Diagram of a typical fisheye excluder BRD. The diagram shows shrimp and fish moving to the codend of the net. Strong swimming fish can exit through the escape opening of the net which is held open by floats and weights, while shrimp passively enter the codend. Credit: Brian Owens, CDFG.

not as well known (Hilborn, 2007). In 2005, the National Marine Fisheries Service (NMFS) designated the soft-bottom areas where pink shrimp effort occurs to be within the lowest sensitivity classification for impacts to seafloor habitat by bottom trawling, and estimated the recovery rates from trawl gear in the pink shrimp fishing grounds to be less than one year (NMFS, 2005). The frequency of disturbance by bottom trawling for pink shrimp is limited by an 8-month open season and a general reduction in fleet size from the Federal fishing capacity reduction program, or vessel buyback program, implemented in the U.S. west coast groundfish fishery by NMFS in 2003. The voluntary vessel buyback program relinquished a total of 85 pink shrimp permits coastwide, 31 of which were California permits (Federal Register, 2003). The semi-pelagic trawl gear used in the pink shrimp fishery may also have less impact on benthic communities than other cold-water shrimp gear types (Roberts, 2005); however, this remains speculative as there are no known direct pink shrimp trawl gear impact studies.

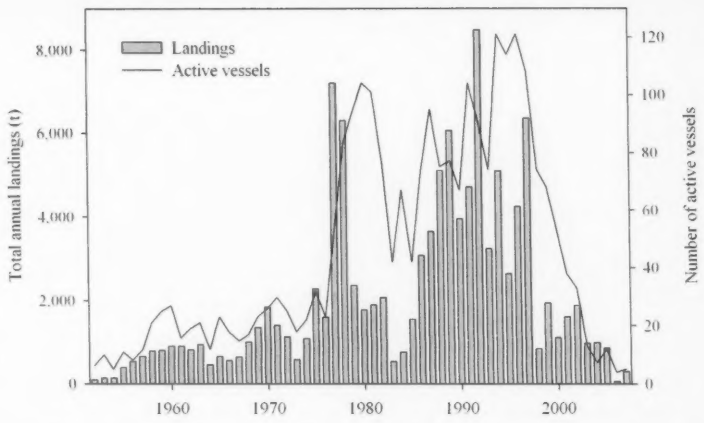


Figure 7.—Total annual commercial landings (t) and number of active vessels in the California pink shrimp fishery from 1952 to 2007. Source: Market receipt data from CFIS (2008).

## Pink Shrimp Catch from 1992 to 2007

Commercial landing receipts (market receipts) are required for every commercial landing in California including pink shrimp. We used CDFG market receipt and vessel license data from 1992 to 2007 to analyze the total annual landings, average annual price-per-pound received by fishermen, total annual ex-vessel revenue, number of active vessels in the fishery by gear type (single rig or double rig), fishing periods, ports in which pink shrimp were landed, number of permits sold, and inactive permits in the California pink shrimp trawl fishery.

Total annual landings fluctuated greatly from 1992 to 2007, ranging from a historical high of 8,474 t in 1992 to a historical low of 63 t in 2006 (Table 1, Fig. 7). The fishery was consistently more productive from 1987 to 1997 compared to any other period in its 56-year history, and the number of active vessels reflected the trends in annual landings (Table 1, Fig. 7). In 1998, the landings decreased to 836 t, which was approximately an eight-fold reduction from 1997 and the lowest annual total since 1983. Although landings recovered somewhat in 1999, they have not exceeded 2,000 t since 1997, and have plummeted to record lows in the last 2 years (Table 1, Fig. 7). The dramatic decline in California's annual landings in recent years has resulted in a drop of its contribution to the total U.S. west coast pink shrimp catch. From 2000 to 2005, the California portion of the total U.S. pink shrimp catch was 8%, and only 1% and 3% in 2006 and 2007 respectively (Fig. 8) (PacFIN[5]).

The market value for pink shrimp landed in California also fluctuated dramatically from 1992 to 2007. The average annual ex-vessel price (price-per-pound) received by fishermen in the California pink shrimp fishery ranged from a high of $0.72/lb in 1995 to a low of $0.32/lb in 2003 (Table 1). The average annual price-per-pound rose considerably from 1993 to 1994 and stayed relatively high until 2001, when it fell to $0.34/lb and was less than $0.40/lb each

**Table 1.—Characteristics of the California pink shrimp fishery from 1992 to 2007. Source: Market receipt data from CFIS (2008).**

| Year | Landings (t) | Ex-vessel revenue[1] | Price-per-pound | Number of Vessels | | |
|---|---|---|---|---|---|---|
| | | | | Active | Single-rig | Double-rig |
| 1992 | 8,474 | $16,880,933 | $0.35 | 90 | 59 | 31 |
| 1993 | 3,233 | $6,442,816 | $0.36 | 74 | 50 | 24 |
| 1994 | 5,092 | $10,152,951 | $0.59 | 121 | 76 | 45 |
| 1995 | 2,624 | $5,234,887 | $0.72 | 114 | 72 | 42 |
| 1996 | 4,242 | $8,466,195 | $0.60 | 121 | 76 | 45 |
| 1997 | 6,351 | $12,683,019 | $0.41 | 108 | 60 | 48 |
| 1998 | 836 | $1,670,492 | $0.58 | 74 | 46 | 30 |
| 1999 | 1,924 | $3,846,121 | $0.53 | 68 | 34 | 34 |
| 2000 | 1,115 | $2,230,852 | $0.52 | 53 | 28 | 25 |
| 2001 | 1,592 | $3,185,198 | $0.34 | 38 | 15 | 23 |
| 2002 | 1,867 | $3,737,900 | $0.38 | 33 | 10 | 23 |
| 2003 | 974 | $1,950,827 | $0.32 | 13 | 1 | 12 |
| 2004 | 992 | $1,988,454 | $0.44 | 7 | 0 | 7 |
| 2005 | 859 | $1,722,424 | $0.48 | 12 | 1 | 11 |
| 2006 | 63 | $127,297 | $0.46 | 4 | 0 | 4 |
| 2007 | 289 | $579,848 | $0.47 | 5 | 2 | 3 |
| Average | 2,533 | $5,056,263 | $0.47 | 58 | 33 | 25 |

[1]Ex-vessel revenue from 1992 to 2007 was adjusted for inflation to year 2007 dollars.

[5]PacFIN. Pacific Coast Fisheries Information Network. Pac. States Mar. Fish. Commiss., Seattle, Wash. Retrieved 12 May 2008 (http://www.psmfc.org/pacfin/).

year through 2003. Since 2004, the average annual price-per-pound leveled out to an average of $0.46/lb from 2004 to 2007 (Table 1). The Oregon pink shrimp fleet experienced similar market value conditions this decade, although they received an average price-per-pound of $0.08/lb less than the California fleet from 2000 to 2006 (Table 1; ODFW[3]). Both fleets received an average price-per-pound of $0.47/lb in 2007. This price is significant for the Oregon fleet because it was $0.10/lb more compared to 2006, and the price is expected to continue increasing (ODFW[3]).

The Oregon pink shrimp fishery was recently certified in accordance with the Marine Stewardship Council's (MSC) Principles and Criteria for Sustainable Fishing, which is the world's first sustainable shrimp certification under this program (MSC[2]; Hannah[6]). However, the same increase in market value may not occur in California because the vessels that are permitted in California and land pink shrimp in California ports are not MSC certified.

The total annual ex-vessel revenue brought into California's economy from the pink shrimp fishery was computed by multiplying the total annual landings by the average annual price-per-pound. From 1992 to 1999, the total annual ex-vessel revenue averaged $8,172,000 (all revenue values have been adjusted for inflation to 2007 dollars). From 2000 to 2007, the total annual ex-vessel revenue averaged $1,940,000, which is a four-fold decrease compared to the 8-year period from 1992 to 1999 (Table 1).

The number of active vessels has generally reflected the trends in annual landings (Table 1, Fig. 7). The number of active vessels in the fishery has decreased steadily over the course of this decade. The use of double rig vessels in the entire U.S. west coast pink shrimp fishery has steadily increased since the 1970's because they are approximately 1.6 times more effective than single rig vessels (PFMC[1]). The percentage of double rig vessels in the California fleet

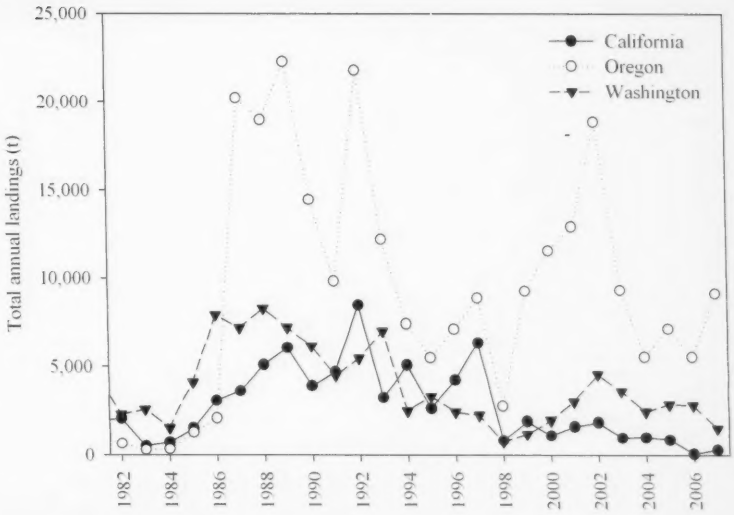


Figure 8.—Total annual commercial landings (t) of pink shrimp in California, Oregon, and Washington from 1982 to 2007. Source: CFIS (2008) and PacFIN(text footnote 5).

was 30% in the late 1970's (PFMC[1]), 38% and 39% during the 1980's and 1990's respectively, and 66% from 2000 to 2007 (Table 1). Although the entire California fleet consisted of double rig vessels in 2004 and 2006, there were two single rig vessels that participated in the fishery during the 2007 season (Table 1). Similarly, nearly all of the current pink shrimp vessels operating in Oregon and Washington are double rig (Hannah[6]; Wargo[7]).

Pink shrimp are landed in California primarily during the late spring and summer of each year in northern region ports (Point Conception to the Oregon border). From 1992 to 2007, nearly 83% of the total annual pink shrimp catch was landed in Eureka, followed by 12% in Morro Bay, 4% in Fort Bragg, and less than 1% in the combined port areas of Monterey, Bodega Bay, Santa Barbara, San Francisco, and Los Angeles (CFIS, 2008). In the most recent years of the fishery (2001–07), over 99% of the annual catch was landed in northern region ports, particularly the Eureka area, and no pink shrimp have been landed in ports south of Morro Bay since 2003 (Table 2).

There have been a significant number of inactive permits in the fleet in recent years for both management regions (Table 2). For example, in 2006, a record low of four of the 40 permitted vessels in the northern region actively participated in the fishery. Historically, both the number of permits sold and the percentage of active vessels are considerably less in the southern region compared to the northern region. This difference may be explained by the infrequent occurrence of pink shrimp in commercial quantities south of Point Conception.

A combination of factors may be attributed to the decrease in fishery production in terms of annual pink shrimp landings and active vessels in California in recent years (Tables 1 and 2). Two factors directly limited the size of the fleet, including the 2003 Federal vessel buyback program and the establishment of a limited entry fishery in the northern management region. The 2003 vessel buyback program reduced the fleet size in the California pink shrimp fishery. Of the 31 California pink shrimp permits relinquished from the buyback program

[6]Hannah, R. W., Oregon Department of Fish and Wildlife, Marine Resources Program, 2040 S.E. Marine Science Dr. Newport, OR 97365. Personal commun., Feb. 2008.

[7]Wargo, L. Washington Department of Fish and Wildlife, 1111 Washington St. SE, Olympia, WA 98501. Personal commun., Feb. 2008.

Table 2.—Number of permits sold, number of active vessels, and annual commercial landings (t) in the two management regions for the California pink shrimp fishery from 2001 to 2007. Source: CDFG License and Revenue Branch and market receipt data from CFIS (2008).

| | Southern region[1] | | | Northern region[2] | | |
|---|---|---|---|---|---|---|
| Year | Permits sold | Active permits | Landings (t) | Permits sold | Active permits | Landings (t) |
| 2001 | 56 | 6 | 0.8 | 78 | 32 | 1,591 |
| 2002 | 57 | 7† | 0.7 | 80 | 26† | 1,866 |
| 2003 | 46 | 4 | 0.1 | 78 | 9 | 974 |
| 2004 | 38 | 0 | 0.0 | 47 | 7 | 992 |
| 2005 | 35 | 1† | 0.0 | 43 | 12† | 859 |
| 2006 | 21 | 1† | 0.0 | 40 | 4† | 63 |
| 2007 | 21 | 1 | 0.0 | 39 | 4 | 289 |
| Average | 39 | 3 | 0.2 | 58 | 13 | 948 |

[1] Refers to California waters south of Point Conception.
[2] Refers to California waters north of Point Conception.
† In 2002, 2005, and 2006, one vessel landed pink shrimp in both management regions.

Table 3.—The number of processing plants that bought pink shrimp in California from 1992 to 2007. Source: CFIS (2008).

| Year | No.[1] | Year | No.[1] |
|---|---|---|---|
| 1992 | 7 | 2000 | 7 |
| 1993 | 8 | 2001 | 4 |
| 1994 | 11 | 2002 | 2 |
| 1995 | 12 | 2003 | 3 |
| 1996 | 13 | 2004 | 2 |
| 1997 | 16 | 2005 | 2 |
| 1998 | 8 | 2006 | 2 |
| 1999 | 8 | 2007 | 1 |

[1] Number of processing plants that processed at least 1,000 lbs (0.45 t) of pink shrimp in California each year, according to CFIS (2008).

(Federal Register, 2003), 18 had landed at least 2 t of pink shrimp in California ports from 2000 to 2003. The northern management region was established as a limited-entry fishery in 2001, thereby creating a cap for the number of vessels allowed to participate (California Code of Regulations, 2008a). Moreover, the decrease in fishery production in recent years may also be attributed at least in part to environmental conditions that negatively affect recruitment (Frimodig et al., 2008; MSC[2]). As with other short-lived pandalid shrimp species, pink shrimp stocks are highly variable from year to year (Hannah, 1993; 1999; Perry et al., 2000; MSC[2]). Since the center of pink shrimp distribution occurs off the Oregon coast (Dahlstrom, 1970; PFMC[1]), the population may fluctuate more at the edges of their range such as California (Hannah[6]).

In addition to the fleet reduction from the 2003 vessel buyback program, only a fraction of the permitted fleet (<10%) in both the northern and southern regions have landed pink shrimp in California ports since 2004 (Table 2). The reduced fishery participation in California this decade may be largely price-driven. The average price-per-pound received by fishermen from 2000 to 2007 is $0.43 compared to $0.52 in the 1990's (Table 1), and may be the result of considerable changes that have occurred in the processing sector. From 1992 to 1997, there was an average of 11 processing plants in California that bought pink shrimp (Table 3). However, the number of processing plants has decreased nearly every year since 1997 reaching a low of only one in 2007 (Table 3). Fuel prices have also risen substantially in recent years. According to the U.S. Energy Information Administration[8], there was an 85% increase in diesel fuel sold in California from 2000 to 2007. The increased fuel prices have undoubtedly limited fishing participation as well as the trucking and distribution costs of the product. Additionally, many pink shrimp permit holders also hold Federal groundfish permits.

Fishermen may have targeted groundfish species such as Pacific hake over pink shrimp more in recent years because they fetched a higher price or were preferred by processors. Pacific hake is the most abundant groundfish off the U.S. west coast and supports a valuable domestic commercial fishery (Ressler et al., 2007). Lastly, market prices and demand for pink shrimp appear to be negatively affected through increased competition from other cold-water shrimp, especially the larger-sized northern shrimp, *Pandalus borealis*, harvested on the east coast of North America. The collapse of Atlantic cod, *Gadus morhua*, stocks in the North Atlantic Ocean during the late 1980's and 1990's led to a considerable surge in both biomass and fishing effort of northern shrimp (Lilly et al., 2000; Worm and Myers, 2003), and a subsequent increase in demand for northern shrimp in the U.S. and Canadian markets. The northern shrimp fishery is the most important cold-water shrimp fishery in the Northern Hemisphere in terms of commercial landings (Roberts, 2005; Lem, 2006), and the U.S. west coast pink shrimp fishery has a proportionally smaller impact on ex-vessel prices (Gallagher et al., 2004).

[8]U.S. Energy Information Administration. Retrieved 20 June 2008, from http://www.eia.doe.gov.

## Catch per Unit of Effort

Pink shrimp CPUE was estimated for California permitted vessels fishing and catching pink shrimp in ocean waters adjacent to California by matching reported logbook effort and catch with market receipt data from 2000 to 2007 using a single-rig equivalency (SRE) conversion (PFMC[1]). This standardization accounts for the difference in effort between double-rig and single-rig vessels, so that direct comparisons can be made throughout the fleet. Logbook compliance in the California pink shrimp trawl fishery is expressed as the frequency of known fishing trips where the required logs are submitted to the CDFG (California Code of Regulations, 2008b). Compliance rates for the California pink shrimp trawl fishery ranged from 20% to 70% with an overall rate of 53% from 2000 to 2007 (Table 4). In contrast, the compliance rates for the limited-entry U.S. west coast groundfish trawl fishery operating in ocean waters adjacent to California averaged 87% from 2002 to 2007 (PacFIN[5]). Reported logbook effort (SRE hours) was adjusted using annual compliance rates to calculate the estimated total effort for each year from 2000 to 2007 (Table 4). However, CPUE was instead calculated from only those trips in which data for both logbook effort and official landings records were available.

**Table 4.—CPUE, effort, compliance, and extrapolated effort in the California pink shrimp fishery from 2000 to 2007. Source: CDFG pink shrimp logbook data and market receipt data from CFIS (2008).**

| Year | CPUE (kg/SRE h) | Effort (SRE h) | Compliance percent | Est. effort (SRE h) |
|---|---|---|---|---|
| 2000 | 315 | 1,823 | 53% | 3,441 |
| 2001 | 436 | 1,449 | 55% | 2,634 |
| 2002 | 372 | 2,667 | 52% | 5,128 |
| 2003 | 291 | 1,303 | 34% | 3,832 |
| 2004 | 340 | 2,094 | 67% | 3,125 |
| 2005 | 289 | 1,383 | 53% | 2,609 |
| 2006 | 239 | 43 | 20% | 215 |
| 2007 | 478 | 179 | 70% | 255 |
| Average | 345 | 1,368 | 53% | 2,655 |

The statewide estimated trawl effort (SRE hours) for pink shrimp from 2000 to 2007 ranged from a high of 5,128 h in 2002 to a low of 215 h in 2006 (Table 4). Fishing effort in southern California occurred off the Santa Barbara coast and comprised less than 1% of the overall statewide effort over this period (Fig. 9a). Effort occurred primarily in northern California, including 39% in the Eureka area and 40% in the Crescent City area, while 19% occurred in the Morro Bay area, and less than 1% occurred in the Monterey area (Fig. 9a). Although seven landings of pink shrimp were made in the Bodega Bay and Fort Bragg areas, effort and CPUE were not estimated for these ports because only two of the seven trips were in the logbook database.

Annual pink shrimp CPUE (kg/SRE hour) from 2000 to 2007 ranged from a low of 239 kg/h in 2006 to a high of 478 kg/h in 2007 with an average CPUE of 345 kg/h (Table 4). Although logbook compliance was relatively high in 2007 at 70%, effort was low and the relatively high CPUE was influenced by one especially successful trip. There was a north to south gradient in CPUE, with the highest CPUE occurring in Crescent City (330 kg/h) and Eureka (386 kg/h), followed by the Morro Bay (302 kg/h) and Santa Barbara areas (28 kg/h) (Fig. 9a). The low CPUE for the Santa Barbara area may be due to unsuccessful exploratory trips during the 2000 and 2001 seasons, since only one trip landed more than 136 kg (0.14 t). The monthly average CPUE from 2000 to 2007 peaked in May (569 kg/h) and was lowest in September (199 kg/h), whereas monthly effort peaked in August (330 SRE h) (Fig. 9b).

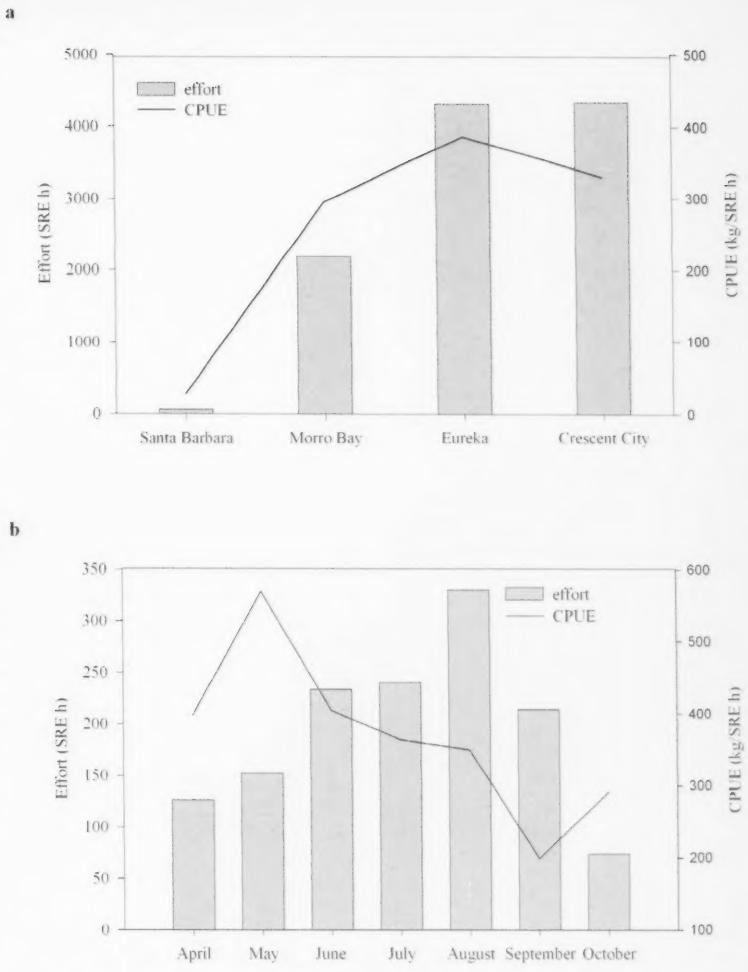


Figure 9.—Total trawl effort (SRE h) for pink shrimp and average CPUE (kg/SRE h) by geographic area from 2000 to 2007 (Fig. 9a). Average pink shrimp effort (SRE hours) and CPUE (kg/SRE hours) by month from 2000 to 2007 (Fig. 9b). Source: CDFG pink shrimp logbook data and market receipt data from CFIS (2008).

Overall, from a geographical context, fishing effort and CPUE were highest off northern California (Fig. 9a). Increased fishing effort on the north coast may be explained by the close proximity to processing plants and the most productive shrimp bed in the state. From 2001 to 2007, few pink shrimp processors occurred in the California marketplace (Table 3), and an average of 68% of the state's total pink shrimp landings was processed in Eureka (CFIS, 2008). The northern most and largest pink shrimp bed in California is the most productive bed historically. This bed extends from Eureka to approximately 10 km north of the California–Oregon border (Fig. 2), also making it the closest bed in California to the center of the species' range off the central Oregon coast (Dahlstrom, 1970; PFMC[1]).

Fishing effort and CPUE varied substantially on a monthly and yearly basis (Table 4, Fig. 9b). Overall fishing effort was mostly limited to summer months, and there was an overall trend of decreasing monthly CPUE from May to September. These trends are most likely explained by market conditions, the availability of the resource, or a combination of the two. The market for pink shrimp in California can be very restrictive in terms of when and where pink shrimp are purchased and processed. For example, in 2007, pink shrimp were landed exclusively in Eureka and processed, only from June to September, by a single buyer in Eureka (CFIS, 2008). The decreasing monthly CPUE trend is expected considering pandalid shrimp typically form dense seasonal aggregations that affect fishery catch rates (Balsiger, 1981). CPUE may also be related to pink shrimp availability which is dependent upon environmental conditions. For example, short-term CPUE for pink shrimp has been positively correlated with environmental factors, such as wind stress, water temperature, and salinity (Perry et al., 2000).

### Bycatch

Trawl nets used in shrimp fisheries are typically built with mesh sizes smaller than those used to target benthic finfish species, and therefore can capture a wide size range of finfish as bycatch because some species commonly occur on shrimp fishing grounds. The amount and composition of bycatch in shrimp trawl fisheries around the world has been a concern for decades because approximately 85% of their total estimated bycatch is discarded (Alverson et al., 1994). Bycatch is either: 1) discarded because it is an unmarketable, prohibited, quota-managed, or regulatory discard species; or 2) retained and sold as marketable incidental catch. Shrimp and benthic finfish trawl fisheries account for over half of the total estimated discards in the world, and tropical shrimp trawl fisheries have the highest discard rates of any fishery in the world (Kelleher, 2005). Since the mandatory requirement of BRD's, discard rates in the U.S. west coast pink shrimp fishery are minimal compared to other worldwide shrimp fisheries (Table 5).

Managers involved in the U.S. west coast pink shrimp fishery, particularly those at the ODFW, have actively researched methods of reducing bycatch since the early 1990's. Although no data has been collected on BRD's directly from the California pink shrimp fishery, extensive research on the efficacy and differences among BRD types has been conducted by the ODFW (Hannah and Jones, 2007; Hannah et al.[9, 10]). The ODFW research results may apply to the California fishery since the vessels in the California fleet tend to use gear similar to that used by the Oregon fleet. The two most notable gear innovations resulting from the ODFW research include: 1) modifications to the traditional footrope, and 2) the use of BRD's in the pink shrimp fishery.

The Oregon pink shrimp fleet switched from the traditional "tickler chain" style of footrope to a roller/ladder style of footrope in the 1990's, which effectively reduced the bycatch of small rockfish and flatfish (Hannah and Jones, 2000). The footrope configurations are semi-pelagic, elevating the net approximately 30–90 cm above the seafloor, while the trawl doors and the center of the nets are in contact with the seafloor (Hannah[6]).

Since the early 1990's, a great deal of research has been focused on the development and experimentation of BRD's in shrimp and prawn trawl fisheries around the world (Kennelly, 2007). Pink shrimp fishermen and the ODFW began experimenting with BRD's in response to especially high abundances of Pacific hake during the 1990's on the shrimp grounds off California, Oregon, and Washington (Hannah et al.[9]).

A recent study by Hannah and Jones (2007) indicates the use of BRD's resulted in a 66–88% reduction in total fish bycatch. Bycatch percentages ranged from 32–61% prior to the use of BRD's, and decreased to an average of 8% when BRD's were used. The MSC certification recently applied to the Oregon pink shrimp fishery is attributed mostly to the use of BRD's. The pink shrimp trawl fishery off the U.S. west coast has recently been described as "one of the cleanest shrimp fisheries in the world" (MSC[2]). Additionally, the Monterey Bay Aquarium and Blue Ocean Institute have recently indicated that pink shrimp harvested off California, Oregon, and Washington is a good choice for environmentally conscious consumers (Roberts, 2005; Blue Ocean Institute[11]).

CDFG market receipt data from 1998 to 2006 indicate that the amount of marketable incidental groundfish landed with pink shrimp in California has declined from 11.5 t in 1998 to less than 0.3 t in 2002, and no marketable incidental groundfish was landed in subsequent years (Table 6). Significant reductions of marketable incidental groundfish were also demonstrated in Oregon and Washington (Table 6), thus removing the economic incentives to use less efficient BRD's (Hannah and Jones, 2007). Additionally, the use of BRD's in the U.S. west coast pink shrimp fishery

**Table 5.—Top weight-based discard to landed target catch ratios by geographic region. Source: Alverson et al. (1994) and for Oregon coast only, Hannah and Jones (2007).**

| Shrimp trawl fishery | Pounds discarded per pounds of shrimp landed |
|---|---|
| Trinidad | 32.4 |
| Indonesia | 26.5 |
| Australia | 24.5 |
| Sri Lanka | 24.3 |
| U.S., Gulf of Mexico | 22.7 |
| Mexico | 21.4 |
| India, west coast | 18.7 |
| U.S., southeast coast | 17.6 |
| Persian Gulf | 9.3 |
| Brazil | 9.0 |
| India, east coast | 8.4 |
| Malaysia | 6.6 |
| Senegal | 6.0 |
| North Sea | 3.2 |
| Newfoundland | 3.0 |
| U.S., Oregon coast | 0.1 |

[9]Hannah, R. W., S. A. Jones, and V. J. Hoover. 1996. Evaluation of fish excluder technology to reduce finfish bycatch in the ocean shrimp trawl fishery. Oreg. Dep. Fish Wildl., Mar. Resour. Program, Newport, Oreg., 46 p.

[10]Hannah, R. W., S. A. Jones, and K. M. Matteson. 2003. Observations of fish and shrimp behavior in ocean shrimp (*Pandalus jordani*) trawls. Oreg. Dep. Fish Wildl., Mar. Resour. Program, Newport, Oreg., 28 p.

[11]Blue Ocean Institute. 2005. Guide to ocean friendly seafood species score card: pink shrimp (retrieved 20 July 2007 from http://www.blueoceaninstitute.org/seafood/species/139.html).

has changed the bycatch species composition from commercially important large fish species to primarily smaller fish species with little or no commercial value (Hannah and Jones, 2007).

Rigid-grate excluders are widely considered to be the most effective of the three allowed BRD types in reducing groundfish bycatch (Hannah and Jones, 2007; Hannah et al.[9, 10]). Soft-panel excluders have been demonstrated to be effective in reducing groundfish bycatch, although excessive shrimp loss and other problems have also been associated with this design (Hannah et al.[9, 10]). Fisheye excluders were banned in Oregon and Washington in 2003 because they were found to be much less effective in excluding groundfish species when compared to rigid-grate and soft-panel excluders (Hannah and Jones, 2007; Hannah et al.[10]).

The current usage of BRD's in the California pink shrimp fleet was documented via a telephone survey we conducted in 2007 and 2008 with pink shrimp fishermen who participated (i.e. landed shrimp) in the fishery in at least one of the fishing seasons from 2005 to 2007. The 10 fishermen surveyed represented 58% of the active fleet in the 2005 season, 75% of the active fleet in the 2006 season, and the entire active fleet in the 2007 season. Results from the phone survey indicate that 90% of the current California fleet use rigid-grate excluders, and 10% use fisheye excluders (Table 7). In the current Oregon pink shrimp fleet, 93% use rigid-grate excluders, and 7% use soft-panel excluders (Table 7). BRD use appears to be similar in the Washington pink shrimp fleet, which typically consists of approximately 24 active vessels. WDFW contacted between 15 and 20 active fishermen during the spring and summer of the 2006 fishing season. All of the fishermen reported using rigid-grate excluders, except for one who reported using soft-panel excluders (Wargo[7]).

Bar spacing on rigid-grate excluders ranges from 29 to 51 mm in the current California pink shrimp fleet and 25 to 51 mm in the current Oregon pink shrimp fleet, with the average bar spacing being slightly larger in the California fleet (Table 7). The State of Washington is considering reducing the allowable bar spacing on rigid-grate BRD's from 51 to 37 mm, because the majority of the fishermen reported using bar spacing of 37 mm (Wargo[7]). Recent research suggests that decreasing the bar spacing to 19 mm or less on rigid-grate excluders may further reduce bycatch rates to well below 5% of the total catch by weight (Hannah and Jones, 2007).

None of the California fishermen contacted in the phone survey were active in the southern region. While there has essentially been no fishery in the southern region in recent years, it could become viable depending on the unit price-per-pound, market demand, and oceanic environmental conditions that affect availability of shrimp on the southern fishing grounds.

Additionally, the southern region pink shrimp fishery is designated by the state as an open access fishery with no cap on the number of potential permit holders. Pink shrimp fishermen in the southern region have historically used single rig vessels, and they have reported that soft-panel and fisheye excluders are preferred because rigid-grate excluders are crushed when the codend is wrapped on the net reel (McCorkle[12]). Hinged, or foldable, rigid-grate excluders have been designed to roll onto the stern reel of double- or single rig shrimp vessels (Fig. 10), and offer a possible alternative to soft-panel or fisheye excluder designs. Hinged rigid-grate excluders reduce the bending of the BRD when the net is reeled on top of it, and they can be constructed to fold either forward or backward (ODFW[13]). According to the 2007–08 CDFG phone survey, the majority of the California fishermen contacted reported using hinged rigid-grate excluders. Since 2003, both double- and single rig vessels in the Oregon pink shrimp fleet have successfully used hinged rigid-grate excluders (ODFW[13]).

**Table 6.—Amount of marketable groundfish bycatch brought in for vessels in the Federal open access pink shrimp fishery for U.S. west coast states from 1998 to 2006. Source: Market receipt data from CFIS (2008) and PacFIN(text footnote 5).**

| State | Year | No. of vessels | Landings (t) |
|---|---|---|---|
| California | 1998 | 21 | 11.5 |
| | 1999 | 19 | 13.4 |
| | 2000 | 13 | 3.1 |
| | 2001 | 8 | 0.7 |
| | 2002 | 2 | 0.3 |
| | 2003 | 0 | 0.0 |
| | 2004 | 0 | 0.0 |
| | 2005 | 0 | 0.0 |
| | 2006 | 0 | 0.0 |
| Oregon | 1998 | 53 | 130.0 |
| | 1999 | 51 | 187.1 |
| | 2000 | 42 | 120.0 |
| | 2001 | 33 | 77.3 |
| | 2002 | 28 | 31.1 |
| | 2003 | 3 | 1.2 |
| | 2004 | 3 | 1.9 |
| | 2005 | 2 | 0.1 |
| | 2006 | 0 | 0.0 |
| Washington | 1998 | 19 | 64.2 |
| | 1999 | 15 | 42.9 |
| | 2000 | 15 | 45.5 |
| | 2001 | 17 | 25.9 |
| | 2002 | 15 | 20.4 |
| | 2003 | 2 | 0.2 |
| | 2004 | 2 | 0.1 |
| | 2005 | 4 | 0.0 |
| | 2006 | 1 | 0.0 |

**Table 7.—Summary of the results from the CDFG 2007/2008 telephone survey on BRD usage reported by active pink shrimp fishermen in the California fishery during the 2005 to 2007 fishing seasons compared with results reported by ODFW on active pink shrimp fishermen in the Oregon fishery during the 2007 fishing season ODFW (text footnote 3).**

| Item | California fleet | Oregon fleet |
|---|---|---|
| Percent using rigid-grate BRD's | 90% | 93% |
| Percent using fisheye excluders | 10% | 0% |
| Percent using soft-panel excluder | 0% | 7% |
| Average bar spacing (mm) on rigid-grate BRD's | 37 | 32 |
| Range of bar spacing (mm) on rigid-grate BRD's | 29–51 | 25–51 |

## Conclusions

To review the California pink shrimp trawl fishery from 1992 to 2007, we 1) analyzed fishery-dependent data, 2) evaluated gear developments and key management measures, and 3) interviewed fishermen who have actively participated in the California pink shrimp fishery in recent years. During the 16-year study period (1992–2007), the fishery has experienced multiple regulatory changes, several gear innovations, and a reduction in fishery production.

The contribution of California's landings to the total U.S. pink shrimp catch

[12]McCorkle, M. Southern California Trawlers Association, 6 harbor Way, Box 101, Santa Barbara, CA 9310. Personal commun., Jan. 2008.

[13]ODFW. 2004. 15th Annual pink shrimp review. Oreg. Dep. Fish Wildl., Mar. Resour. Program, Newport, Oreg., 8 p. (online at http://www.dfw.state.or.us/mrp/publications).

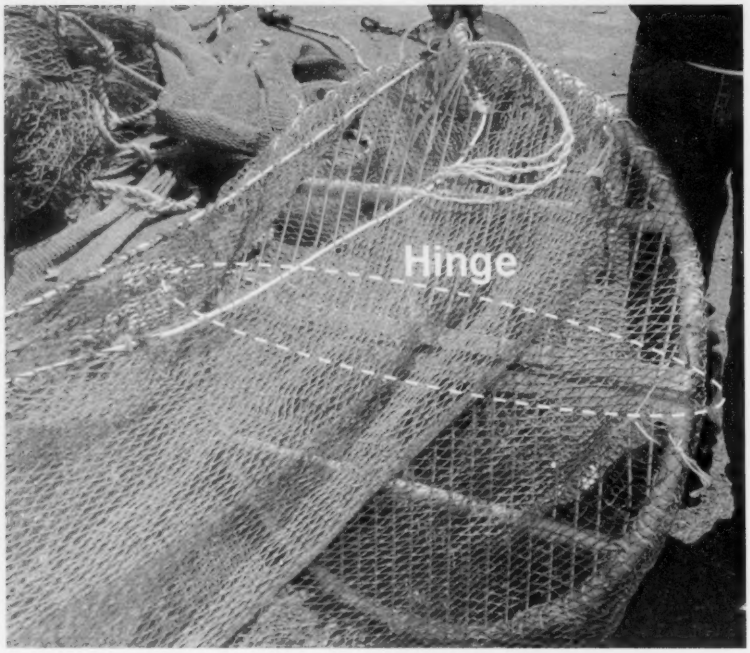


Figure 10.—Photograph of a hinged, or folded, rigid-grate BRD. Credit: Adam Frimodig, CDFG.

is currently negligible (PacFIN[5]). The current pink shrimp fishery is also minor compared to other fisheries within the state. In 2007, there were 21 California fisheries with greater landings than the pink shrimp fishery (CFIS, 2008). The reduction of fishery production, particularly in recent years, appears to be primarily driven by market conditions. However, the resource itself appears to be healthy, and the recruitment and abundance of pink shrimp appears to be mostly influenced by oceanic environmental conditions (Hannah and Jones, 1991; Hannah, 1993; 1999; Perry et al., 2000). Pink shrimp recruitment is predicted to be strong in the foreseeable future, particularly off southern Oregon and potentially northern California (ODFW[14]).

Fishermen participation in the California pink shrimp fishery has been low in recent years, although there is potential for growth if market conditions become more favorable. Although there is a cap on the number of vessels allowed in the limited entry northern region fishery (California Code of Regulations, 2008a), only a fraction of the fleet capacity has been active in recent years. Many pink shrimp permit holders also hold groundfish permits and switch their gear throughout the year depending on the more profitable or available target species. The demand for pink shrimp harvested off the U.S. west coast may increase based on the recent MSC certification of the Oregon pink shrimp fishery (MSC[2]) and the recent designation by the Monterey Bay Aquarium and Blue Ocean Institute of pink shrimp harvested off the U.S. west coast as a good choice for environmentally conscious consumers (Roberts, 2005; Blue Ocean Institute[11]). An increase in market demand could provide more incentive for California pink shrimp permitees to participate in the fishery.

The essential fishery data collected to monitor and accurately assess the California pink shrimp fishery has been reduced since the 1991 fishing season compared to historical data collection. CDFG commercial landing receipt data is a reliable record of catch, but trawl logbook records for the pink shrimp fishery are currently incomplete. Valid or complete logbook data are available prior to 1992 and from 2000 to 2007. Logbook data from 1992 to 1999 has gaps, due in part to low compliance by fishermen, that may affect the accuracy of spatial and temporal calculations of effort, location, intensity, and CPUE.

The pink shrimp logbook form for California is antiquated, and could be revised to reflect changes in the fishery. Logbook records could be improved by capturing information on BRD type and bar spacing on rigid-grate excluders as well as estimates of fish bycatch and shrimp discard. Adding these fields to the form would make the California and Oregon logbooks comparable (ODFW[3]; Hannah[6]). Moreover, instructions for recording fishing trip locations in the current logbook format are outdated. Fishery participants are instructed to record locations in Loran, despite the fact that most modern vessels utilize more accurate Global Position System based technology for navigation. This has resulted in inefficient and unnecessary reporting of trawl locations in Loran units, which is less accurate and more time consuming for CDFG staff to convert to latitude/longitude units.

The quality and accuracy of the logbook information provided by fishermen could also be improved through increased port-side communication, particularly in the two main ports that pink shrimp are landed (Eureka and Morro Bay). Increased port-side communication between biologists and fishermen would also help to clarify any confusing or missing logbook and market receipt data, provide an educational tool to keep fishermen better informed of current regulations and management issues, and increase fishermen compliance in submitting their logbooks. Port-side communication between biologists or samplers and fishermen in the Oregon pink shrimp fishery has proven to be very effective, which is evident by their

[14]ODFW. 2009. 20th Annual pink shrimp review. Oreg. Dep. Fish Wildl., Mar. Resour. Program, Newport, Oreg., 11 p. (online at http://www.dfw.state.or.us/mrp/publications).

excellent logbook compliance rates (Hannah[6]). Two recently implemented Federal management measures, mandatory observer coverage and the requirement of a vessel monitoring system aboard vessels fishing in Federal waters, will provide additional data on the pink shrimp fishery.

In addition to logbook deficiencies, the dockside biological market sampling program for pink shrimp in California ports ended in 1992. Reinstating the program would provide valuable fishery-dependent information on the health of pink shrimp stocks in California that is currently lacking, such as size, age composition, and sex ratio of the landed catch. The fishery is not currently operating at its full capacity, however if it were to operate near its full capacity, the sampling program is recommended. Fishery-independent investigations, such as determining the efficacy of BRD's used in the pink shrimp fishery, have already been done extensively by ODFW. Other research, such as documenting habitat impacts associated with bottom trawl gear, would also provide valuable fishery-independent information.

## Acknowledgments

We extend our gratitude to the pink shrimp fishermen who participated in our telephone survey. The information they provided greatly improved our understanding of the current fishery. Robert W. Hannah and Lorna Wargo were also particularly helpful in providing valuable information about the pink shrimp fisheries in Oregon and Washington. We also thank Tom Barnes, Sandra Owen, Robert W. Hannah, and two anonymous reviewers for providing useful comments which improved the manuscript.

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# Extending the Bajo de Sico, Puerto Rico, Seasonal Closure: An Examination of Small-scale Fishermen's Perceptions of Possible Socio-economic Impacts on Fishing Practices, Families, and Community

FLÁVIA C. TONIOLI and JUAN J. AGAR

## Introduction

Worldwide reef fish fisheries are in peril. Newton et al. (2007), who studied reef fish fisheries in 49 island states, found that current landings exceed sustainable levels by 64%. Similarly, work by Sadovy de Mitcheson et al. (2008) suggests that 79% of the documented spawning aggregations around the world are undergoing substantial declines. In U.S. Caribbean waters, commercially valuable reef fish species such as Nassau grouper, *Epinephelus striatus*, and goliath grouper, *E. itajara*, remain overexploited despite commercial harvest bans since the early 1990's (Appeldoorn et al., 1992; Sadovy and Eklund, 1999). Reef fish species, especially groupers, are particularly vulnerable to overexploitation due to their life history characteristics, which include slow growth, delayed reproduction, sedentary behavior, and highly aggregated spawning events (Sadovy and Eklund, 1999).

Though reef fish fisheries only account for a small fraction of global landings (2–5%), they are an important source of sustenance, income, and employment for many coastal communities (Pauly et al., 2003; Sadovy, 2005; Newton et al., 2007). Hence, policy makers are interested in management tools that rebuild depleted fish stocks, protect the structure, function, and resilience of coral ecosystems, and maintain the well-being of coastal communities (Newton et al., 2007).

In the Commonwealth of Puerto Rico, local fishery management agencies have favored the use of seasonal closures to conserve and protect reef fish populations, particularly those that exhibit predictable and highly aggregated spawning behaviors. While seasonal closures provide for the sustained economic participation of small-scale fishermen, they afford limited conservation benefits. Hence, fishery managers are increasingly interested in novel management tools such as marine protected areas that provide greater protection for reef fish stocks. Unfortunately, despite a growing literature examining the biological performance of marine protected areas, there is a paucity of socio-economic evaluations (NRC, 2001; Christie et al., 2002; Christie, 2004).

This study investigates small-scale fishermen's views on the Caribbean Fishery Management Council's (CFMC) proposals to lengthen the current Bajo de Sico seasonal closure to afford additional protection to snapper-grouper spawning populations and associated coral reef habitats. The intent of this study is to provide decision-makers with a first-hand account of the reported socio-economic impacts of the various proposals as perceived by small-scale fishermen.

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*ABSTRACT—Despite considerable conservation efforts, many reef fish fisheries around the world continue to be in peril. Many are vulnerable to overexploitation because they have predictable and highly aggregated spawning events. In U.S. Caribbean waters, fishery managers are increasingly interested in advancing the use of closed areas as a means for rebuilding reef fisheries, protecting coral reef habitats, and furthering ecosystem-based management while maintaining the sustained participation of local fishing communities. This study details small-scale fishermen's views on the Caribbean Fishery Management Council's proposals to lengthen the current Bajo de Sico seasonal closure off the west coast of Puerto Rico to afford additional protection to snapper-grouper spawning populations and associated coral reef habitats.*

*Drawing on snowball sampling techniques, we interviewed 65 small-scale fishermen who regularly operate in the Bajo de Sico area. Snowball sampling is a useful method to sample difficult-to-find populations. Our analysis revealed that the majority of the respondents opposed a longer seasonal closure in the Bajo de Sico area, believing that the existing 3-month closure afforded ample protection to reef fish spawning aggregations and that their gear did not impact deep-water corals in the area. Whilst fishermen's opposition to additional regulations was anticipated, the magnitude of the socio-economic consequences described was unexpected. Fishermen estimated that a year round closure would cause their gross household income to fall between 10% and 80%, with an average drop of 48%. Our findings suggest that policy analysts and decision-makers should strive to better understand the cumulative impacts of regulations given the magnitude of the reported socio-economic impacts; and, more importantly, they should strive to enhance the existing mechanisms by which fishermen can contribute their knowledge and perspectives into the management process.*

## Management Background

Following the collapse of Nassau grouper stocks in the late 1970's, Puerto Rican fishermen began targeting smaller, less frequently marketed groupers such as red hind, *E. guttatus*; and coney, *Cephalopholis fulva*, which then became the dominant commercial grouper species (CFMC, 1985; Matos-Caraballo, 1997; 2002). In 1996, concern about the declining condition of the red hind population resulted in a regulatory amendment to the Shallow Water Reef Fish Fishery Management Plan of Puerto Rico and the U.S. Virgin Islands (CFMC, 1996). This regulatory amendment established three seasonally closed areas: Bajo de Sico, Tourmaline, and Abrir la Sierra. These three areas were closed to all fishing activities (excluding coastal pelagic and highly migratory species) from 1 December through the last day of February (CFMC, 1996; Aguilar-Perera et al., 2006). The Bajo de Sico area was selected because several commercially important reef fish species, including red hind, form spawning aggregations in this site. After the adoption of the 1996 regulatory amendment, the Commonwealth of Puerto Rico implemented compatible regulations.

The Bajo de Sico area encompasses both Federal waters and Puerto Rico territorial waters with a 60:40 split, respectively (Fig. 1). The 3,119-hectare site contains a submerged seamount with an extensive deep terrace reef formation. The reef lies across the entire northwest section of the seamount at depths between 45 and 90 m over a relatively flat, gently sloping, hard bottom terrace (García-Sais et al., 2008). Deep hermatypic coral formations[1] are found on the reef top and the upper slopes of the seamount (García-Sais et al., 2008). Rhodolith reefs occur along the gently sloping terraces at depths below 40 m (García-Sais et al., 2008). The reef top and walls serve as important residential habitats for commercially valuable grouper and snapper assemblages, including Nassau; yellowfin, *Mycteroperca venenosa;* yellowmouth, *M. interstitialis*; and red hind groupers and yellowtail, *Ocyurus chrysurus;* schoolmaster, *Lutjanus apodus*; dog, *L. jocu*; and cubera, *L. cyanopterus*, snappers. In addition, the seamount serves as a foraging area for large pelagic fishes such as wahoo, *Acanthocibium solanderi*; dolphin-fish, *Coryphaena hippurus*; tunas, *Thunnus spp.*; and marlins, *Makaira nigricans*. The reef system at Bajo de Sico also serves as an important foraging and residential habitat for the endangered hawksbill turtle, *Eretmochelys imbricata*.

In 2005, the Comprehensive Amendment to the Fishery Management Plans (FMP) of the U.S. Caribbean to Address Required Provisions of the Magnuson-Stevens Fishery Conservation and Management Act prohibited the use of bottom tending gears (i.e. traps, bottom longlines, gillnets, and trammel nets) in various seasonally closed areas, including Bajo de Sico, to enhance protection of essential fish habitats (CFMC, 2005). In addition, the CFMC prohibited the harvest of several snapper-grouper species during their spawning season. Current regulations ban the harvest of red, *E. morio*; black, *M. bonaci*; tiger, *E. fuscoguttatus;* yellowfin; and yellowedge, *E. flavolimbatus*; groupers between 1 February and 30 April and prohibit the harvest of black, *L. griseus*; blackfin, *L. bucanella*; vermilion, *Rhomboplites aurorubens;* and silk, *L. vivanu*, snappers between 1 October and 31 December. There is also a lane, *L. synagris*,, and mutton, *L. analis*, snapper closure that extends from 1 April though 30 June and a red hind harvest prohibition for the west coast of Puerto Rico that runs from 1 December through the last day of February.

Currently, the CFMC is contemplating management proposals that would afford additional protection to snapper-grouper spawning populations and local coral reef habitats in the Bajo de Sico area. The first management alternative would maintain the current closure for all fishing between 1 December and the last day of February. The second management option would extend the closure from 3 to 6 months. This extended closure would prohibit all fishing activities (excluding coastal pelagic and highly migratory species) for 6 months and retain the current year round gear restrictions.

Two potential 6-month closures have been suggested: one extending from 1 October until 30 March, and the other one extending from 1 December until 30 May. The third management proposal would close the area year round to provide full protection for spawning aggregations of large snappers and groupers as well as coral reef habitats. The closure would prohibit all fishing activities (excluding coastal pelagic and highly migratory species) for 12 months and retain current, year round gear restrictions.

## Methodology

In the fall of 2008, 65 informal, voluntary conversations were held with small-scale fishermen from the municipalities of Aguadilla, Aguada, Rincón, Añasco, Mayaguez, and Cabo Rojo (Fig. 1). Snowball sampling techniques were used to identity those small-scale fishermen who regularly fished in the Bajo de Sico area since these would be most likely impacted by the proposed management alternatives. These in-person, open-ended exchanges elicited information on their opinions and beliefs about the performance of the Bajo de Sico closure following the 2005 bottom tending gear ban, and their views on the existing management proposals which could potentially lengthen the Bajo de Sico seasonal closure.

In snowball sampling, interviewees suggest other potential subjects from their social network (Bernard, 2002). This technique is frequently used to sample difficult-to-find populations. It was selected because Puerto Rican fishing trip reports do not collect information on the area fished. In addition, in recent years many fishermen had stopped reporting (or misreported) their landings following the implementation

[1]Hermatypic corals contain and depend upon zooxanthellae (algae) for nutrients.

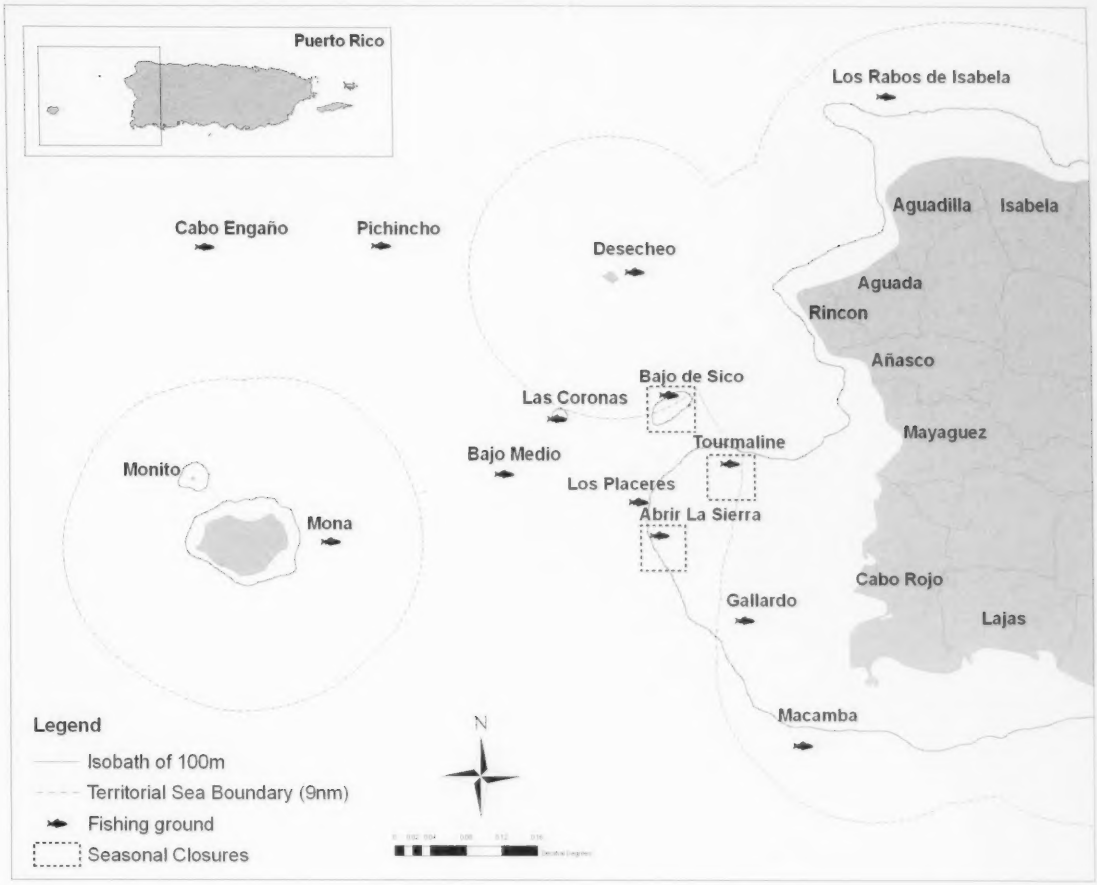


Figure 1.—Bajo de Sico area and surrounding fishing grounds.

of Puerto Rican Regulation No. 6768, which was adopted on 11 March 2004 (Matos-Caraballo[2,3]).

This regulation mandated that fishermen operating in Puerto Rican waters (0–9 nmi) had to report their landings and fishing related income. These new reporting requirements generated considerable angst since fishermen could potentially be forced to pay income taxes, and could lose public assistance and health care benefits. Under current regulations, full-time fishermen have a 90% tax exemption over their fishing related income whereas part-time fishermen have no tax exemptions.[4] Additionally, this regulation mandated the purchase of permits and licenses for several species such as queen conch, *Strombus gigas*; spiny lobster, *Panulirus argus*; land crab, *Cardisoma guanhumi*; and sirajo gobies, *Sicydium plumiere*. Fishermen were also upset about the increased minimum sizes of several commercially important species, especially silk snapper (Matos-Caraballo[2]). Local fisheries personnel from Puerto Rico's Department of Natural and Environmental Resources (PRDNER) and presidents of the local fish cooperatives ("villas pesqueras" as they are locally known) served as liaisons to local fishermen.

## Results and Discussion

This section describes the main demographic characteristics of the fishermen interviewed and discusses fishermen's perceptions regarding the

[2]Matos-Caraballo, D. 2008. Lessons learned from the Puerto Rico's commercial fishery, 1988–2008. Paper submitted to Gulf and Caribbean Fisheries Institute, Gosier, Guadeloupe, French West Indies, Nov. 2008.

[3]Daniel Matos-Caraballo, of Puerto Rico's Program of Fisheries Statistics in Mayaguez, stated that the relatively high sample size likely accounted for most of the active fishermen who operated in the Bajo de Sico area. Personal commun., 28 Oct. 2008.

[4]Existing regulations require that full-time fishermen demonstrate that they derived 50% or more of their total income from fishing whereas part-time fishermen must show that they derive a minimum of 20% of their income from fishing.

socio-economic performance of the current seasonal closure and anticipated socio-economic impacts of the proposed alternatives. Throughout our conversations, fishermen stated that they were indifferent about the timing of the two 6-month proposals since they would have the same adverse impacts on their livelihoods. Hence, when discussing the impacts of the various alternatives, we simply discuss the 6-month and year-round alternatives.

### Demographic Profile of the Respondents

The majority of the respondents were male captains whose fishing experience ranged from 1 to 53 years. About 50% of the respondents had less than 24 years of fishing experience. Fifty-two percent of the interviewees were full-time commercial fishermen, 40% were part-time commercial fishermen, 5% were charter operators and 3% were subsistence fishermen (Table 1).

Fishermen reported using a variety of gears such as hook and line, bottom line, and longline to target snapper-grouper species, including silk snappers, red hind, and queen snappers, *Etelis oculatus*.[5] Sixty percent of them stated that they fished with only one crew. About half of the fishermen reported taking 1–3 trips per week (Table 1). Many of them land their catch at local fish cooperatives (Fig. 2). Household sizes were relatively small, averaging 2–3 dependents per household. Income derived from fishing was found to play an important role in the household's economy. About 65% of the respondents derived more than 50% of their household income from fishing activities in 2008 (Table 1).

Figure 2.—Traditional fishing boats lying in front of a fish cooperative ("villa pesquera"), Aguadilla, Puerto Rico, October 2008.

## Fishermen's Views on the Seasonal Closure

### Impacts on Fishermen's Ability to Support Themselves and Their Household

Prior to discussing fishermen's perceptions about the anticipated economic and social impacts of the proposed management alternatives, it is useful to review earlier work to provide a backdrop to our findings. According to Griffith et al. (2007), who conducted a socio-economic assessment of the Bajo de Sico seasonal closure prior to the 2005 bottom tending gear ban, only 32% of the respondents believed that the seasonal closure adversely impacted their livelihoods. Their study also found that 51% of the fishermen did not believe that the seasonal closure negatively impacted their ability to support themselves or their families. Our study revealed that the 2005 bottom tending gear ban made it harder for fishermen to earn a living from fishing. Fishermen explained that the increasing number of burdensome regulations, higher fuel costs, and declining catches had forced them to become more reliant on non-fishing occupations.

When we asked about the likely impacts of the various management proposals on their ability to support themselves and their family, fishermen stated that the 6-month closure would likely reduce their gross household incomes between 10% and 80% with an average loss of 43%. In the case of the year round closure, they estimated that their gross household income would fall between 10% and 80%, with an average drop of 48%. When we parsed these results by income derived from fishing (0–49% vs. 50–100%), we obtained analogous results underscoring the importance of the area to local fishermen. We found that, on average, the more fishing dependent fishermen (i.e. 50–100% grouping) would lose 44% of their gross household income if the Bajo de Sico closure was extended for 6 months. This same group also reported that their gross household

**Table 1.—Demographic characteristics of respondents.**

| Demographic characteristics | Frequency | Percentage |
|---|---|---|
| Type of fishermen | | |
| Captain | 55 | 84.6 |
| Crew | 10 | 15.4 |
| Number of weekly trips | | |
| 0–3 | 29 | 47.5 |
| >3 | 32 | 52.5 |
| Status | | |
| Full-time | 34 | 52.3 |
| Part-time | 26 | 40.0 |
| Charter | 3 | 4.6 |
| Subsistence | 2 | 3.1 |
| Number of dependents | | |
| None | 8 | 12.3 |
| 1 | 5 | 7.7 |
| 2 | 10 | 15.4 |
| 3 | 18 | 27.7 |
| >3 | 24 | 36.9 |
| Percentage of household income derived from fishing | | |
| 0–20 | 6 | 9.5 |
| 20–50 | 16 | 25.4 |
| 51–75 | 11 | 17.5 |
| >75 | 30 | 47.6 |

[5]Hook and line and bottom line refer to vertical line gears. Generally, bottom lines have electric reels and a larger number of hooks than the regular hook and line gear.

income would drop by 49% if there was a year round closure. In contrast, the less fishing dependent group (i.e. 0–49%) stated that they would lose 41% of their gross household income if the seasonal closure was lengthen by an additional 3 months, and by 45% if there was a year round closure.

Despite the anticipated sharp declines in income, most fishermen pledged to continue fishing, revealing a high degree of fidelity to their profession. They reported that they would attempt to compensate any loss of income by seeking part-time work outside the fishery. Most fishermen noted that non-fishing jobs were either not available or hard to secure, especially since many of them were already working part-time jobs.[6]

Bureau of Labor Statistics (2009), preliminary and not seasonally adjusted, unemployment statistics for 2008 validate their contention. These statistics show relatively high unemployment rates throughout the region (e.g. Aguadilla, 12%; Aguada, 12.8%; Rincón, 12.7%; Añasco, 12.2%; Mayaguez, 12.7%; and Cabo Rojo, 9.4%).[7] Construction was often cited as the most likely employment alternative. Few fishermen believed that the fishing sector could absorb additional workers.

We also inquired how the proposed alternatives may impact their annual round. Most fishermen remarked that they would not switch gears nor target different species if the seasonal closure was extended. They mentioned that they would continue using bottom line, longline, and hook and line gears to catch snappers and groupers. Fishermen's overall unwillingness to switch to other fishing gears and species was fairly consistent across municipalities. They remarked that it would be very onerous to switch to other fishing gears given the expense of purchasing new equipment and permits. Nevertheless, most fishermen suggested that lengthening the closed season would impact their fishing practices in a number of ways.

First, they would lose access to one of the most productive snapper-grouper and baitfish grounds in the area. They observed that foregoing access to this area by an additional 3 months would cause their average landings per trip to fall between 20% and 90%, with an average decline of 48%. In contrast, a year round closure would cause their average landings per trip to drop between 25% and 100%, with an average decline of 57%. When we disaggregated these results by income derived from fishing (0–49% vs. 50–100%), we obtained comparable results highlighting the importance of the area. We found that, on average, the more fishing dependent group (i.e. 50–100%) would have their landings per trip drop by 49% if the Bajo de Sico closure was extended for 6 months. This same group also reported that their landings per trip would fall by 55% if there was a year round closure. On the other hand, the less fishing dependent group (i.e. 0–49%) stated that they would lose 47% of their landings per trip if the seasonal closure was lengthen by an additional 3 months, and lose 57% if there was a year round closure.

During our exchanges, fishermen stressed that the Bajo de Sico area has a de facto 6-month closure since September and October are known months of poor weather[8] and strong currents, and there are overlapping seasonal bans for the harvest of various snappers, including silk snapper (Table 2). Fishermen who regularly operate in the Bajo de Sico area reported that silk snapper was their most important target species, followed by red hind and queen snapper. In addition, fishermen complained about the overlapping seasonal snapper-grouper harvesting bans, which last 9 months (Table 2). Fishermen claimed that the cumulative impacts of extending the seasonal closure by an additional 3 months (i.e. 6-month closure) coupled with the 2 months of traditional bad weather and rough seas, and the rolling snapper-grouper harvest bans, essentially felt "like a year round closure."[9]

Additionally, fishermen noted that extending the seasonal closure would increase travel time and associated fuel costs to other fishing grounds since they would have to circumnavigate the Bajo de Sico area and other seasonally closed areas to maintain their landing levels. Fishermen stated that if additional restrictions were placed on the Bajo de Sico area, then Abrir la Sierra and Tourmaline would become their preferred alternative fishing grounds. Other important fishing grounds mentioned were Pichincho, Corona del Sur, Desecheo, Mona, Gallardo, Macamba, Bajo Medio, Los Placeres, Cabo Engaño, and Los Rabos de Isabela (Fig. 1).

While current fishing regulations do not preclude fishermen from transiting through closed areas, most fishermen steer clear from them when fish are on board to avoid being stopped and possibly fined by the U.S. Coast Guard. The simultaneous closure of the Bajo de Sico, Tourmaline, and Abrir la Sierra areas and probability of being detected and fined by the U.S. Coast Guard provide fishermen with a strong incentive to avoid these areas altogether (Fig. 1). Hence, extended closures would force fishermen to travel farther in search for new aggregations—making fishing trips longer, less profitable, and more dangerous.

Fishermen noted that as they take longer trips and travel farther out, their operating costs would increase too. When asked about the likely increases in their operating costs, fishermen stated that operating costs per trip (mainly fuel) would increase between 5% and 175%. Fishermen offered iden-

[6]Puerto Rican fishermen regularly engage in numerous temporary, low-skilled employment opportunities (i.e. odd jobs or "chiripas" as they are known locally) to supplement their household incomes (Griffith and Valdés-Pizzini, 2002; Perez, 2005; Griffith et al., 2007; Agar et al., 2008).

[7]Bureau of Labor Statistics. 2009. Unemployment Rate Statistics for the Commonwealth of Puerto Rico. Online at http://data.bls.gov/cgi-bin/dsrv, accessed 24 March 2009.

[8]Matos-Caraballo (2007) notes that fishing tends to slow down at the height of the Puerto Rican hurricane season, which encompasses the months of August and September. For example, hurricane Debbie and tropical storm Jeannie hit Puerto Rico on 22 August 2000 and 15 September 2004, respectively (Matos-Caraballo, 2007).

[9]In reality, the proposed 3-month extension (i.e. 6-month closure) essentially translates into a 10-month closure due to the overlapping snapper-grouper seasonal harvest bans (Table 2).

**Table 2.—Cumulative impacts of snapper-grouper seasonal harvest bans and bad weather season on management proposals.**

| Current regulations and management proposals | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Red hind fishery closure (W. Puerto Rico only) | r[1] | r | | | | | | | | | | r |
| Black, blackfin, vermilion, and silk snapper fishery closure | | | | | | | | | | s[2] | s | s |
| Red, black, tiger, yellowfin, and yellowedge grouper fishery closure | | g[3] | g | g | | | | | | | | |
| Lane and mutton snapper fishery closure | | | | m[4] | m | m | | | | | | |
| Traditional months of poor weather | | | | | | | | | w[5] | w | | |
| Proposed Management Alternative # 1: (Status quo) | Closed | Closed | g | m, g | m | m | | | w | s, w | s | Closed |
| Proposed Management Alternative # 2 (a): 6-month closure (1 Oct–30 March) | Closed | Closed | Closed | m, g | m | m | | | w | Closed | Closed | Closed |
| Proposed Management Alternative # 2 (b): 6-month closure (1 Dec–30 May) | Closed | Closed | Closed | Closed | Closed | m | | | w | s, w | s | Closed |
| Proposed Management Alternative # 3: 12-month closure | Closed | Closed | Closed | Closed | Closed | Closed | Closed | Closed | Closed | Closed | Closed | Closed |

[1] The "r" refers to the months of the harvest ban of red hind.
[2] The "s" refers to the months of the harvest ban of black, blackfin, vermilion, and silk snappers.
[3] The "g" refers to the months of the harvest ban of red, black, tiger, yellowfin, or yellowedge groupers.
[4] The "m" refers to the months of the harvest ban of lane and mutton snapper.
[5] The "w" refers to the 2 months of traditional rough seas.

tical ranges for both the 6-month and the year round alternatives. On average, fishermen estimated that their operating costs would increase by 57% if the current 3-month closure was extended to 6 months and by 59% if the area was closed year round. The median percentage increase in operating costs for both the 6-month and year round closure proposals was around 50%. Fishermen also stated that lenthening the seasonal closure would curtail their access to baitfish. If the closed season was extended, then they would likely forgo this baitfish rich area, given its distance from the shore, requiring them to either fish for it elsewhere or purchase it. Both options would increase their operating costs.

When we queried them about the likely drop in gross revenues per trip, fishermen offered ranges between 20% and 80% for the 6-month closure and between 25% and 100% for the year round closure. On average, fishermen estimated that the 6-month closure would reduce their gross revenues by 47%, whereas the year-round closure would decrease their gross revenues by 55%. The relatively small difference in the estimates for the 6 and 12-month closures is consistent with the belief that the 6-month closures would feel "like a year round closure," as previously discussed. While most fishermen were concerned about the dire economic impacts of lengthening the closure, few said that they would exit the fishery since "fishing was all they knew." Many fishermen stated that the potential lengthening of the Bajo de Sico closure would force them to become even more reliant on part-time work as fishing regulations become more stringent.

Fishermen also complained that most marine reserves (e.g. Mona, Monito, and Desecheo) are being sited on the west coast of Puerto Rico. They observed that the increasing number of area and season closures creates confusion as to when, where, and which species they can harvest. Fishermen felt that extending the Bajo de Sico closure would be counterproductive since most of the fleet would shift its effort to the Abrir la Sierra and Tourmaline areas, which they believe show signs of overexploitation. Tourmaline has always been subject to higher exploitation levels due to its proximity to coastal communities and favorable habitat for red hind spawning activity (Marshak, 2007).

Despite fishermen's aversion to proposed management alternatives, they acknowledged that the existing Bajo de Sico seasonal closure had been effective in protecting spawning aggregations, particularly those for red hind and silk snapper. These results are consistent with Griffith et al.'s (2007) study, which found that 83% of their respondents believed that the Bajo de Sico effectively protected spawning aggregations. However, most of our respondents were quick to point out that the existing 3-month closure offered ample protection to the spawning aggregations.

When we inquired whether the closure had enhanced fish abundance within and outside the area, most fishermen disagreed. These findings contradict Griffith et al.'s (2007) results. Their study reported that 79% of the respondents believed that the Bajo de Sico seasonal closure increased the abundance of a variety of snapper-grouper species, including silk, queen, blackfin, lane, yellowtail, and mutton snappers and red hind. Griffith et al. (2007) also reported that 81% of the respondents stated having perceived greater fish abundance outside the seasonal closure, especially red hind and queen and silk snappers.

While we are uncertain as to the reasons for the discrepancy between our findings and Griffith's results, Marshak (2007) suggests that a spillover of female red hind into unprotected areas, and the discovery of previously

unknown concentrations of red hind may have contributed to a transient increase in catch per unit of effort (CPUE) following the implementation of the seasonal closure. However, over time, the CPUE declined in response to lower recruitment and higher fishing effort. This recent CPUE decline may explain fishermen's changing outlook on the closure's performance.

We also inquired about the need to protect corals in this area. Most fishermen questioned the need to protect them since they are found deep in the water column. Fishermen believed that their gears could not impact these deepwater corals. Fishermen also stated that they distrusted the CFMC because they feared that once the Bajo de Sico area is closed, Abrir la Sierra and Tourmaline areas would follow next, forcing them to take longer fishing trips and/or search for part-time jobs outside the fishery. An extended closure would force them to spend more time at sea to land the same amount of catch, which would weaken family cohesion, as they would have less time to spend with family and friends.

### Socio-economic Impacts on Local Fishing Communities

Fishermen believed that the 2005 ban on bottom tending gears had adversely impacted their local communities, particularly fishing families, fish cooperatives, hotels, restaurants, and the support service firms. However, they struggled in articulating the severity of the impact. Griffith et al. (2007) report similar findings. Their study showed that 57% of the respondents felt that the Bajo de Sico seasonal closure created social or economic hardships for local communities.

When we probed about the likely community impacts of the CFMC's proposals, there was widespread consensus that they would severely impact local businesses that are directly and indirectly associated with the fishing industry. However, they had trouble quantifying the incremental impact of the various proposals. They observed that placing additional restrictions on the Bajo de Sico area would impact the entire local harvesting, wholesale, distribution, marketing, retail, and support service chain.

Fishermen stated that extending the closure would increase their operating expenses; however, because of the availability of inexpensive seafood imports, they would have to absorb most of these higher costs. Their inability to pass along these higher costs to the consumer means that the remuneration of both captain and crew would likely decrease since both receive a share of the trip's revenue after deducting operating expenses. Few fishermen stated that the proposed extensions would force them to reduce the number of crew employed since it would be unsafe to run the boat single-handed.

Additionally, fishermen stated that longer closures could potentially weaken kinship relationships.[10] Traditionally, crew members, who receive a share of the boat's income, have provided non-remunerated assistance to the boat owner (e.g. help repairing the vessel and gear) as part of an understood system of obligations (Agar et al., 2008). Since longer closures would reduce the wages available to crew members, they too would be forced to seek additional employment outside the fishery. Thus, crew would have to either reduce or eliminate the time they can dedicate to these non-remunerated activities. Many crew members reported that they were working part-time jobs and for different captains on other boats. These added economic strains could weaken traditional kinship relations and community cohesion, which are based on a set of cultural values of mutual help (Agar et al., 2008).

In addition to lowering crew's income, a longer closure would depress fishing-related expenditures at support businesses such as suppliers of boating and fishing equipment, boat mechanics, ice shops, and fuel stations. Griffith et al. (2007) reported that the commercial sector contributes significantly to local economies through fishing related expenditures. On an island basis, their study found that 71% of vessel construction, 98% of the vessel maintenance, and 94% of the engine maintenance were conducted locally. They also reported that 71% of the fishing gears and 43% of the electronic equipment were purchased locally.

When probed about the likely impacts of longer closures on fish cooperatives, called "villas pesqueras," the majority of the fishermen explained that lower catches would result in fewer employment opportunities, less income, and, more importantly, the potential loss of market share. Fishermen feared that lengthening the closed season would make it harder for them to compete in the marketplace since many restaurants and hotels would be enticed to substitute lower-cost, readily available seafood imports for locally-caught seafood.

Griffith et al. (2007) observed that the number of commercial fishing families has remained stable because they have been able to make a living by providing high quality, fresh fish and shellfish to local seafood markets, restaurants, and hotels. Fishermen often like to state that they "defend themselves with fresh fish (or lobster)" (Griffith et al., 2007). Fishermen believe that their comparative advantage lies in their ability to supply year round fresh seafood since most of the imported seafood is frozen, canned, dried, or otherwise preserved. Table 3 shows the relationship between com-

**Table 3.—Annual commercial landings and seafood imports for Puerto Rico.**

| Year | Reported landings[1] (lbs) | Adjusted landings[2] (lbs) | Imports[3] (lbs) |
|---|---|---|---|
| 2000 | 3,362,722 | 6,276,077 | 195,659,105 |
| 2001 | 3,389,010 | 5,301,956 | 130,482,152 |
| 2002 | 3,272,812 | 4,048,506 | 83,425,022 |
| 2003 | 2,388,761 | 3,364,452 | 89,686,776 |
| 2004 | 1,864,680 | 2,626,310 | 77,047,313 |
| 2005 | 1,569,035 | 2,209,908 | 79,018,305 |
| 2006 | 1,338,924 | 1,761,742 | 79,773,368 |
| 2007 | 1,242,002 | 1,971,432 | 78,597,926 |

[1] Cummings, N., and S. Turner, Southeast Fisheries Science Center, NMFS, NOAA. Personal commun.

[2] These figures have been adjusted for nonreporting and misreporting. Cummings, N., and S. Turner, Southeast Fisheries Science Center, NMFS, NOAA. Personal commun.

[3] San Juan, Puerto Rico Custom District (text footnote 11).

[10] According to Griffith et al. (2007) about 50% of the crew is made up of friends and 31% family members, confirming that kinship relationships play an important role in the supply of labor in these small-scale fisheries.

mercial landings and seafood imports for 2000–07. While these figures show that most of the seafood available is imported, readers are cautioned that both domestic consumption and transshipments to other U.S. ports are included in this import statistic.[11] Unfortunately, the government does not break down domestic consumption and transshipment figures. Given that the current population of Puerto Rico is around 4 million people and tourism accounts for another 5 million visitors[12], it is likely that a high (yet unknown) percentage of these seafood imports are transshipped to other ports on the mainland. Griffith et al. (2007) also note that the availability of seafood imports enables small, family-owned restaurants and hotels to cater to tourists when the supply of fresh local seafood is limited.

Last, the issue of user conflicts was raised during our conversations. The likely crowding of inshore and offshore fishing grounds and the concomitant user conflicts were another source of uneasiness. Fishermen stated that the existing Bajo de Sico seasonal closure had already created crowding on other fishing grounds. Thus, extending the seasonal closure would simply reduce the amount of fishable grounds, increase competition in the remaining open areas, and exacerbate crowding. Fishermen also suggested that conflicts with the recreational sector may arise since they object to recreational fishermen selling their catches at lower prices, especially when they do not have a commercial fishing license. Furthermore, they noted that unlike recreational fishermen, commercial fishermen "do need to catch fish in order to make a living."

## Conclusion

Balancing the need to rebuild overexploited reef fisheries, protect coral reef habitats, and provide for the sustained participation of local fishing communities is at the core of difficult management decisions. Our rapid socio-economic assessment showed that fishermen believe that the Bajo de Sico seasonal closure has effectively protected spawning aggregations, particularly for red hind and silk snapper. The study also found that fishermen were vehemently opposed to management proposals that would extend the seasonal closure. Most fishermen believed that the existing 3-month closure afforded ample protection to spawning aggregations and questioned the need for longer closures. Fishermen complained about the lack of biological assessments of the performance of the closure.

While fishermen's opposition to further regulations was anticipated, the magnitude of the socio-economic consequences described was unexpected. Fishermen reported that the overlapping seasonal snapper-grouper harvest bans and the 2 months of rough seas effectively transform a 6-month seasonal closure into a 10-month de facto seasonal closure. They also reported that the socio-economic impacts of a year round closure were marginally higher than those of a 6-month closure. Fishermen estimated that a 6-month closure would reduce their average landings per trip between 20% and 90%, with an average decline of 48%, whereas a year round closure would decrease their average landings per trip between 25% and 100%, with an average decline of 57%.

Taken together, our results suggest that policy analysts and decision-makers should strive to better understand the cumulative socio-economic impacts of regulations given the magnitude of the reported incremental effects. More importantly, given the sharp differences of opinion regarding the efficacy and need for additional protection measures, fishery managers should strive to progressively integrate fishermen's knowledge and perspectives into the scientific and management discourse. Greater public involvement and communication, information dissemination and compromise may be required to address fishery agencies' conservation goals and fishermen's concerns.

[11]NMFS. 2009. Import statistics by U.S. Import Custom District. Online at http://www.st.nmfs.noaa.gov/st1/trade/annual_data/TradeDataAnnualDistrictAllProducts.html, accessed 24 March 2009.

[12]CIA. 2009. The World Factbook: Puerto Rico. Online at https://www.cia.gov/library/publications/the-world-factbook/geos/rq.html#People, accessed on 2 April 2009.


## Acknowledgments

We would like to express our gratitude to all the fishermen, presidents of fish cooperatives ("villas pesqueras"), and restaurant owners who kindly shared their time and knowledge of the fishery with us. Also, we would like to acknowledge the assistance of Daniel Matos-Caraballo from Puerto Rico's Department of Natural and Environmental Resources who offered valuable insight into Puerto Rican fisheries. Jim Waters, Thomas Jamir, and Aleta Hohn from the NMFS Southeast Fisheries Science Center, and Michael Travis and Stephen Holiman from the NMFS Southeast Regional Office provided useful comments. We are also extremely grateful to Michelle Schärer, who kindly provided us GIS data. Maria Villanueva and Suzana Guedes provided valuable assistance with the development of the GIS maps. We would also like to thank the anonymous reviewers who provided comments on this manuscript. This research was supported by NOAA's Coral Reef Conservation Program.


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# Chartered Trawling on the Brazilian Slope

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*ABSTRACT—Commercial trawling on the Atlantic slope areas off Brazil intensified in the late 1990's owing to the expansion of coastal trawling areas and the operations of a chartered foreign fleet. Between 2000 and 2003, 59 fishing trips conducted by 10 chartered trawlers were intensely monitored by observers and satellite vessel monitoring systems, totaling 9,069 tows and 30,085.2 trawling hours. Fishing operations occurred in northern, northeastern, southeastern, and southern sectors of the Brazilian coast in 60–1,173 m depths. Total retained and processed catch were 8,074.6 t and 6,479.8 t, respectively. Argentine hake,* Merluccius hubbsi*; and Argentine shortfin squid,* Illex argentinus*, were the primary species taken contributing to 41.1% and 28.6% of the overall catch, respectively. The silver John dory,* Zenopsis conchifera*; monkfish,* Lophius gastrophysus*; Brazilian codling,* Urophycis mystacea*; and the black grouper,* Epinephelus nigritus*, composed 23% of total processed catch, and the remaining 7.2% was composed of deep-sea shrimps (family Aristeidae) and other teleosts and elasmobranches. The occupation of slope areas included an early exploratory phase, followed by directed phases of the upper slope (300–500 m), aiming principally at the Argentine hake, and the lower slope (>700 m), targeting valuable concentrations of deep-sea aristeid shrimps. The role of chartering for slope trawling development was critically addressed. We conclude that chartered vessels were efficient explorers and were particularly important in areas not available to the technologically limited national fleet. Because the charters were market-oriented and had elevated profit demands, however, those vessels quickly turned from exploration to exploitation and competed with national trawlers in shallower areas and produced significant impacts on Brazil's modest deep-sea resources.*

## Introduction

Large-scale trawl fishing development around the world has been principally associated with the occupation of productive continental shelf areas (<200 m). The continental slope (200–2,000 m) has been less accessible to trawl fishing owing to the steep and often irregular topography and the generally discrete distribution patterns of targeted fish and shellfish within this area (Gordon et al., 1995; Merret and Haedrich, 1997). In the North Atlantic, although slope trawling was already practiced by Soviet and German vessels by the 1970's, the activity increased nearly 10 years later as the abundance of most shelf resources were greatly reduced and their catch was restricted by intensive regulation (Troyanovsky and Lisovsky, 1995; Gordon, 2001; Gordon et al., 2003). Essential to the process was the identification of profitable deep-water targets, the development of technology to overcome market limitations, and the progressive availability of charts depicting flatter grounds suitable for safe trawling (Gordon et al., 1995; Piñeiro et al., 2001). Led by French trawlers during the 1990's, a multispecies deep-water fishery was well established in areas 800–1,600 m deep mostly in the northeast Atlantic (Charuau et al., 1995; Iglesias and Paz, 1995; Gordon, 2001; Piñeiro et al., 2001; Lorance and Dupoy, 2001). In the tropical southwest Atlantic, however, another decade would go by before any effective commercial deep-water trawling activity was documented.

The continental shelf off Brazil encompasses 911,000 km² bathed mostly by southwest Atlantic waters. Its width varies along the nearly 8,000 km length of the country's coastline being particularly broad at the northern, southeastern, and southern sectors (Rossi-Wongstchowski et al., 2006). In all these sectors, trawling regimes have been established since the 1960's, basically supported by productive shelf stocks like penaeid shrimps, *Farfantepenaeus* spp., and demersal sciaenids (Haimovici et al., 2006a). For nearly 40 years these regimes were confined to the 100 m isobath (Perez et al., 2001), except for scientific surveys that, during this period, mapped slope areas and revealed a few potential resources of uncertain productivity and profitability (Haimovici, 2007).

The interest on occupying deeper waters only arose as a pattern in the national fishing industry when regional trawl fleets, particularly of the southern and southeastern coasts, began to experience economic losses due to overfishing of their main targets and were forced to look for alternatives (Perez et al., 2001). By the late 1990's, a significant number of shrimp and fish trawlers had conducted commercial operations at the shelf break, 100–200 m deep, exploiting profitable multispecies concentrations of pink cusk-eel, *Genypterus brasiliensis*; flounders, *Paralichthys* spp.; skates, family Rajidae; shrimps, *Plesionika longirostris*, and lobsters, *Metanephrops rubellus* (Perez and Pezzuto, 2006). A few years later, these same vessels

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**Table 1.—Summary of fishing trips conducted by chartered trawlers in Brazilian waters between October 2000 and October 2003.**

| Vessel | Beginning of operations | End of operations | Latitude range | Longitude range | Depth range (m) | Number of trips | Number of tows | Trawled hours | Processed production by trip (min–max) | Total processed production (t) |
|---|---|---|---|---|---|---|---|---|---|---|
| *Joana* | 10/26/00 | 01/22/01 | 23°38'S–34°02'S | 41°53'W–51°35'W | 131–460 | 2 | 300 | 1,132.3 | 118.1–141.7 | 259.8 |
| *Insung 207* | 05/23/01 | 07/25/03 | 03°15'S–34°36'S | 40°02'W–54°29'W | 75–720 | 14 | 2,559 | 5,707.9 | 83.9–421.3 | 3,955.5 |
| *Rio Bouzos Uno* | 10/22/01 | 06/27/02 | 23°26'S–27°11'S | 41°10'W–47°03'W | 118–468 | 5 | 708 | 2,111.8 | 73.6–81.8 | 380.5 |
| *Cipi* | 10/04/01 | 02/13/02 | 23°23'S–33°05'S | 41°04'W–50°28'W | 224–492 | 3 | 437 | 1,326.7 | 79.1–98.3 | 272.7 |
| *Nuevo Apenino* | 09/17/01 | 07/30/02 | 23°00'S–32°50'S | 41°01'W–50°23'W | 124–795 | 9 | 932 | 3,474.3 | 32.4–80.5 | 528.2 |
| *Hermanos Vaqueros* | 11/13/01 | 06/13/02 | 23°08'S–28°05'S | 40°10'W–48°58'W | 190–1,173 | 5 | 510 | 2,244.5 | 37.4–63.1 | 204.2 |
| *Emanguluko* | 12/13/01 | 04/01/02 | 19°51'S–33°05'S | 38°02'W–50°28'W | 60–920 | 3 | 244 | 452.4 | 39.0–81.4 | 168.3 |
| *Arneles* | 01/23/02 | 01/11/02 | 24°01'S–31°28'S | 43°06'W–49°46'W | 129–394 | 1 | 18 | 70.7 | 7.7 | 7.7 |
| *Costa Grande* | 04/03/02 | 07/31/03 | 23°05'S–27°08'S | 41°12'W–46°52'W | 220–762 | 10 | 1,742 | 7,173.5 | 11.5–63.9 | 361.1 |
| *Mar Maria* | 08/22/02 | 10/20/03 | 08°14'N–27°38'S | 34°25'W–50°31'W | 203–1,158 | 7 | 1,619 | 6,391.1 | 12.7–92.2 | 341.8 |
| Total/range | | | 08°14'N–34°36'S | 34°25'W–54°29'W | 60–1,173 | 59 | 9,069 | 30,085.2 | 7.7–421.3 | 6,479.8 |

trawled to 200–400 m depths of the slope, first targeting monkfish, *Lophius gastrophysus*, concentrations and later including Brazilian codling, *Urophycis mystacea*; Argentine hake, *Merluccius hubbsi*; and Argentine shortfin squid, *Illex agentinus* (Perez et al., 2002a; Perez and Pezzuto, 2006).

As the regional Brazilian fleets were gradually occupying slope grounds, they were joined by foreign trawlers chartered by national companies as part of a deep-water fishing development program promoted by Brazilian authorities (Perez et al., 2003). These vessels were authorized to operate within the Brazilian Exclusive Economic Zone (EEZ), off the 200 m isobath, and were fully monitored by observers and satellite vessel monitoring system (VMS) in accordance with government regulations.

In essence, these regulations were regarded as instruments to a) promote the desired deep-sea fishing and processing technology transfer and b) assemble general knowledge on new fishing areas, potential deep-water resources, and international markets. Applied to trawlers and other deep-water vessels (i.e. gillneters and potters directed at monkfish and deep-water crabs, *Chaceon* spp., respectively) these instruments constituted the main data source to be utilized by deep-water stock assessments and management plans conducted from 2001 onward (Perez et al., 2002b; 2005; Pezzuto et al, 2006a). Despite the well-defined and mostly industry-oriented objectives, the chartering of vessels for deep-water fishing in Brazil also generated a great concern about potential impacts on untouched stocks and deep-sea ecosystems as well as uncertainties about its sustainability. These concerns were even more critical in light of the conflicting demands of a large and highly overcapitalized national fleet.

This paper describes the slope trawling fishery conducted by chartered vessels off Brazil between 2000 and 2003, including the physical characteristics of vessels and gears, the definition of main targets, the strategies of fishing ground occupation, and spatial and temporal patterns of catch, effort, and catch rates. Along with a previous assessment on the slope-trawling fishery conducted by national vessels (Perez and Pezzuto, 2006), this review is intended to improve our understanding of the status and perspectives of this new deep-water fishing era in Brazil and to critically address the costs and benefits of the chartering policies in such a process.

## Data Sources and Analyses

Analyzed data is from the Chartered Fleet Observers Program developed by Universidade do Vale do Itajaí as part of a scientific cooperation project with Brazilian fishing authorities (Ministry of Agriculture and Special Secretariat for Aquaculture and Fishery). All 59 fishing trips conducted by 10 chartered trawlers between 26 October 2000 and 20 October 2003 (Table 1) were monitored by observers assigned to collect, after each tow, information on fishing areas (position and depth), effort (tow duration), and catch composition. All retained species were identified on board and also on land, through collected specimens and photographic/videographic material. Catches were recorded in "processed weight" and later transformed into "live weight" using conversion indices for each species, as defined by the vessel's crew and/or experimentally by the observers aboard. Catch rates were expressed in kg per trip and kg per hour.

The main targets of chartered trawlers off Brazil were assessed using the method proposed by Biseau (1988). This method quantified, initially, the proportion taken by each species in the total biomass retained by each tow ($c_{i,s}$) as follows:

$$c_{i,s} = \frac{T_{i,s}}{T_i} \cdot 100 \qquad (1)$$

where $T_{i,s}$ is the total biomass of species $s$ in the tow $i$ and $T_i$ is the total biomass obtained by tow $i$. $c_{i,s}$ is then pooled by truncated classes of 1 to 100%, each one denominated Level of Qualification (LQ), and, for each $j^{eth}$ LQ, the sum of the total biomass is calculated for each species $s$ ($TC_{j,s}$). Finally the following equation

$$P_{j,s} = \frac{TC_{j,s}}{T_s} \cdot 100 \qquad (2)$$

where $T_s$ is the total landed biomass of species $s$, calculates the relative contribution (in percentage) of each LQ to the total catch of species $s$ in one fishing trip ($P_{j,s}$). These contributions are presented in a cumulative frequency distribution whose form allows an assessment of the level of directionality of each tow to the retained species (Biseau, 1988).

Catch, effort, catch rates, and fishing targets were analyzed by vessel. Tows conducted in the southeastern and southern sectors of Brazilian coast were also grouped by latitudinal strata (North, north of lat. 25°S; Center, between lat. 25° and 29°S; South, south of lat. 29°S); depth strata (<200 m; 200–399

Table 2.—Summary of chartered trawlers that operated off Brazil from October 2000 to October 2003 including their flag country and their main features.

| Vessel | Flag country | Year of construction | Total length (m) | Engine power (hp) | GT (t) | Storing capacity (t) | Autonomy (days-at-sea) | Crew (workers) |
|---|---|---|---|---|---|---|---|---|
| *Joana* | Portugal | | 60.0 | 1,700 | 890 | 320 | 70 | 32 |
| *Insung 207* | South Korea | 1975 | 56.9 | 2,200 | 925 | 350 | 50 | 41 |
| *Rio Bouzos Uno* | Spain | 1986 | 33.0 | 1,200 | 324 | 80 | 80 | 18 |
| *Cipi* | Spain | 1973 | 39.0 | 870 | 270 | 110 | 70 | 19 |
| *Nuevo Apenino* | Spain | 1998 | 33.0 | 1,000 | 200 | 145 | 60 | 18 |
| *Hermanos Vaqueros* | Spain | 1969 | 27.8 | 490 | 168 | 75 | 50 | 18 |
| *Emanguluko* | Namibia | 1989 | 31.1 | 1,900 | 483 | 100 | 24 | 28 |
| *Arneles* | Spain | 1984 | 75.7 | 1,850 | 789 | 692 | 120 | 30 |
| *Costa Grande* | Spain | 1973 | 30.0 | 800 | 170 | 80 | 50 | 16 |
| *Mar Maria* | Spain | 1998 | 38.4 | 1,200 | 271 | 140 | 80 | 20 |

m; 400–599 m; >600 m); trimesters (I: Jan.–Mar.; II: Apr.– June.; III: July–Sept.; IV: Oct.–Dec.), and years (2000, 2001, 2002, and 2003).

## The Fleet

The chartered trawlers operating off Brazil from October 2000 to October 2003 originated from Spain (7), Portugal (1), Republic of South Korea (1), and Namibia (1). These vessels are described in Table 2. Three vessels (*Joana*, *Insung 207*, and *Arneles*) were noticeably larger (57–76 m long), with powerful engines (1,700–2,200 hp), and able to carry 30–41 men crew and to store 320–692 t of frozen fish. The remaining seven vessels were less robust, running 28–39 m long, 490–1,200 hp engines, 16–20 men crew, and store 75–145 t of frozen fish. Except for the trawler *Arneles* that could operate continuously for 120 days at sea, the chartered trawlers autonomy ranged between 24 and 80 days. All chartered trawlers operating in Brazil were built between 1969 and 1998, being 3–32 years old in 2001.

Table 3.—Physical features of the fishing gear used by chartered trawlers off Brazil from October 2000 to October 2003.

| Vessel | Head rope length (m) | Ground rope length (m) | Use of bobbins | Trawl vertical opening (m) | Mesh size at cod end (mm) | Door weight (kg) |
|---|---|---|---|---|---|---|
| *Joana* | 37.0–56.0 | 18–70 | Frequent | 3.5–4.5 | 135 | 1,250 |
| *Insung 207* | 40.0–90.0 | 55–100 | Frequent | 3.5–7.0 | 70–110 | 1,600–2,500 |
| *Rio Bouzos Uno* | 58.0–65.0 | 60–80 | Frequent | 3.0 | 65–70 | 750–800 |
| *Cipi* | 58.5–67.2 | 70–80 | Occasional | 10.0–15.0 | 60–85 | 620 |
| *Nuevo Apenino* | 33.0–85.0 | 45–100 | Occasional | 2.0–5.0 | 50–90 | 900–1,000 |
| *Hermanos Vaqueros* | 65.4–67.0 | 80 | | 3.0–10.0 | 70 | 500 |
| *Emanguluko* | 38.0–80.0 | 62–95 | Frequent | 2.0–5.0 | 70–120 | 1,600 |
| *Arneles* | 92.0 | 110 | Frequent | 4.0 | 100 | 1,600 |
| *Costa Grande* | 45.0–101.0 | 47–120 | | 1.0–2.5 | 50–80 | 500–650 |
| *Mar Maria* | 40.0–71.0 | 41–85 | Occasional | 2.2–3.0 | 80 | 900 |

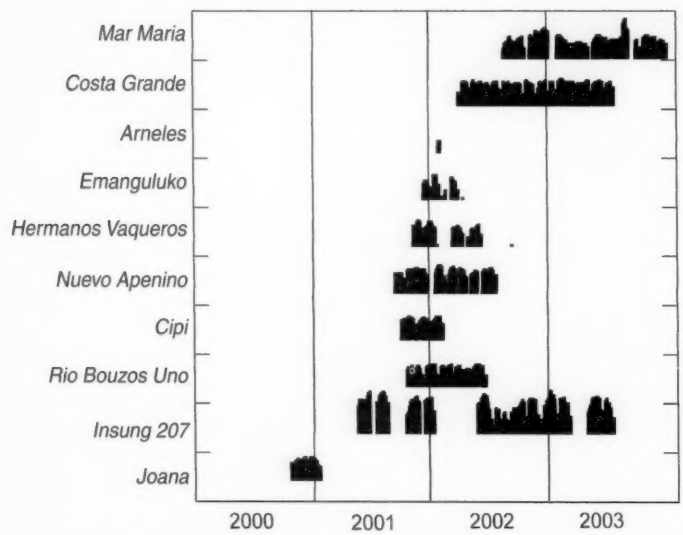



Figure 1.—Temporal distribution of trawls conducted by chartered vessels on slope areas off Brazil from 2000 to 2003. Bar heights are proportional to the number of tows conducted during each day.

Two Spanish vessels (*Cipi* and *Hermanos Vaqueros*) were side trawlers, whereas all the others were stern trawlers. Side trawlers and stern trawlers were single- and double-decked, respectively. In the latter, the lower deck was sheltered and used for catch processing. Various trawl nets were used. Head rope and ground rope dimension ranges were 33–101 m and 41–120 m, respectively (Table 3). Mesh was made of braided or twisted polyethylene and measured 50–120 mm at the cod-end (stretched mesh). These nets were towed at 2.3–3.5 knots and their estimated vertical opening ranged from 3 to 15 m. Doors used weighed between 500 and 2,500 kg. On rough grounds, some trawlers used steel or rubber bobbins at the ground ropes (200–500 mm in diameter). Chains could replace these bobbins when fishing was conducted over smooth, soft ground.

## Fishing Dynamics

Chartered trawlers conducted 59 fishing trips between 2000 and 2003

(Fig. 1) totaling 9,069 tows and 30,085.2 trawling hours (Table 1). Fishing operations occurred in northern, northeastern, southeastern, and southern sectors of Brazilian coast in areas 60 to 1,173 m deep (Fig. 2, 3).

In the southeastern and southern coast, nearly 70% of the tows conducted by the chartered trawlers were between lat. 23°S and lat. 25°S, whereas a secondary fishing area was between lat. 26°S and lat. 29°S (Fig. 3A). Similarly 60% of the total tows were conducted on 300–500 m deep grounds and a secondary depth was at 700–800 m isobaths for 20% of the tows (Fig. 3B). Occupation of the southern and southeastern slope areas resulted in the establishment of three main fishing grounds characterized by concentrations of the most abundant and/or valuable species: Argentine hake, Argentine shortfin squid, and the deep-sea shrimps (family Aristeidae). This process occurred in three consecutive phases: Exploratory, Directed (upper slope), and Directed (lower slope).

Exploratory phase: Established between late 2000 and mid 2001, this phase included the first operations of the trawlers *Joana* and *Insung 207*, which conducted tows along the entire southeastern–southern Brazilian coast between 100–400 m depths (Fig. 3A, 3B). In early 2001, the trawler *Joana* abandoned the Brazilian waters (Fig. 1).

Directed phase of the upper slope: From late 2001 onward, this phase was characterized by the intense exploitation of the two main latitudinal strata, lat. 23°S–25°S and lat. 26°S–29°S, between the 250 and 450 m isobaths (Fig. 3A, 3B). The trawler *Insung 207* which initiated this second phase was joined later by six trawlers, mostly Spanish. Operations directed to the northern and southern latitudinal strata were associated with commercial concentrations of the Argentine hake and the Argentine shortfin squid, respectively. Except for *Insung 207*, all vessels cited above terminated their operations off Brazil during 2002 (Fig. 1).

Directed phase of the lower slope: Initiated in early 2002, this phase was directed at concentrations of deep-sea

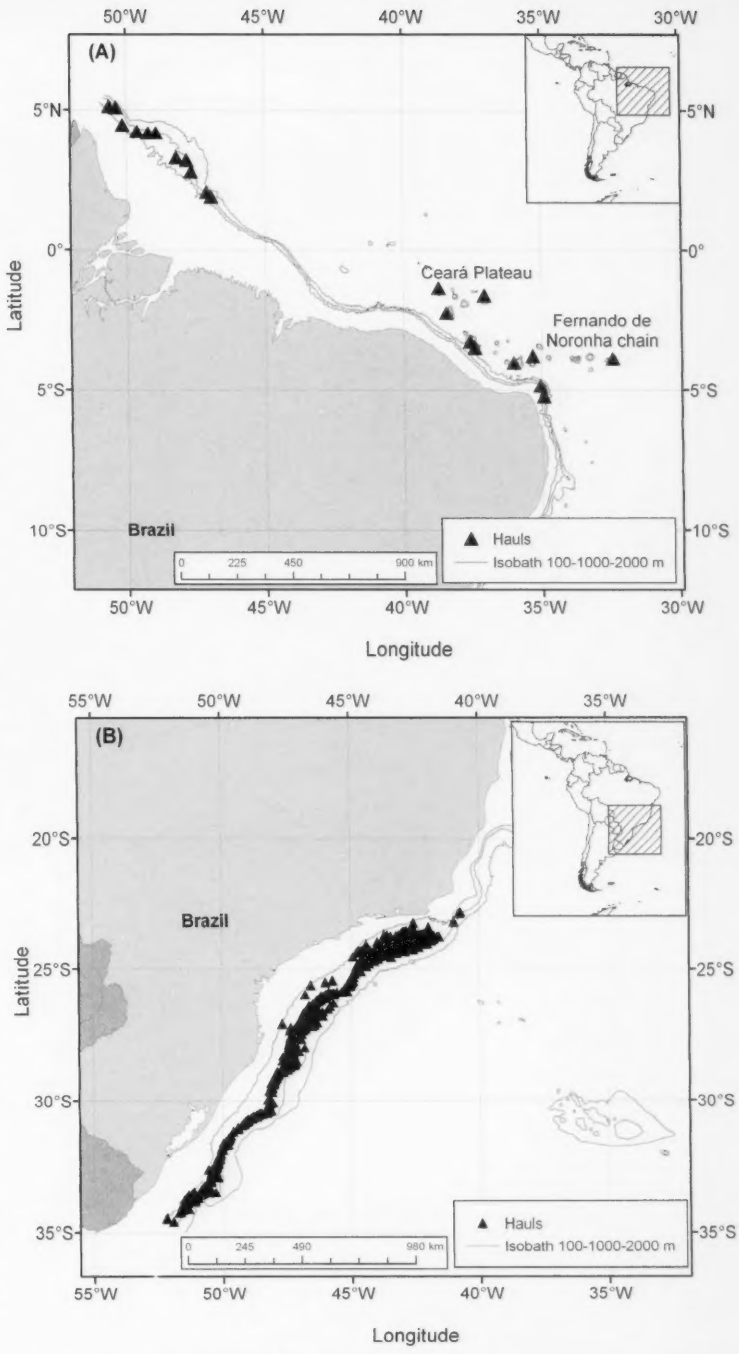



Figure 2.—Spatial distribution of trawls conducted by chartered vessels on slope areas off Brazil from 2000 to 2003. (A) Northern and Northeastern sectors and (B) Southeastern and Southern sectors of Brazilian EEZ.

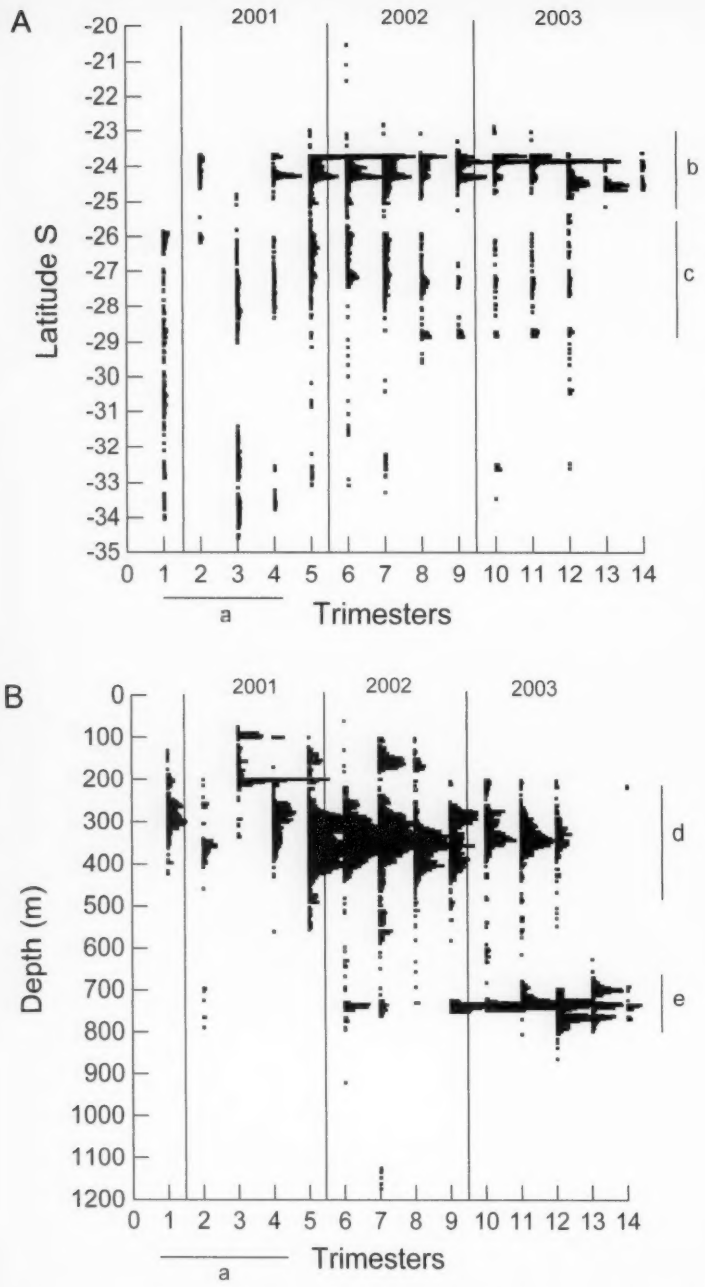



Figure 3.—Latitudinal (A) and depth (B) distribution of trawls conducted by chartered vessels on slope areas off Brazil in 14 trimesters from 2000 to 2003. a. Exploratory phase; b. Directed phase of the upper slope (Argentine hake) and directed phase of the lower slope (aristeid shrimps); c. Directed phase of the upper slope (Argentine shortfin squid); d. Directed phase of the upper slope (Argentine hake and Argentine shortfin squid); e. Directed phase of the lower slope (aristeid shrimps).

shrimps. In 2002 the trawler *Nuevo Apenino* conducted exploratory tows deeper than 700 m obtaining, north of lat. 25°S, the first commercial catches of the "carabinero" or scarlet shrimp, *Aristaeopsis edwardsiana*. By late 2002 two other trawlers initiated the directed exploitation of this species as well as the "moruno" or giant red shrimp, *Aristaeomorpha foliacea*, and "alistado" shrimp, *Aristeus antillensis*, between lat. 24°S and lat. 25°S and the 700–800 m isobaths (Fig. 3A, 3B). After 2002 this fishery expanded with the entry of new chartered vessels and the identification of new fishing grounds north of lat. 19°S (Pezzuto et al., 2006b).

The trawlers *Mar Maria* and *Insung 207* also operated in the northern and northeastern sectors of Brazilian coast. These operations were distributed on a wide longitudinal range concentrating within long. 35°W and long. 38°W (Fig. 2A). Nearly 100 tows were conducted close to the northern boundary of the Brazilian EEZ (long. 48°W–51°W) on depths from 400 to 1,200 m, where moderate catches of deep-sea shrimp were obtained. Operations of *Mar Maria* also concentrated on the flat tops of seamounts that compose the Ceará Plateau and the Fernando de Noronha Chain (Fig. 2A). These seamounts elevate from nearly 1,000 m depths, at their base, to 200 m depths at the top, where the gentle topography was found to be suitable for trawling. Catches in these areas were mostly composed of the black grouper, *Epinephelus nigritus*, whose catch rates decreased rapidly to unprofitable levels forcing this trawler to move to southern Brazil and join the deep-sea shrimp fishery.

### Catches and Targets

The chartered trawlers produced altogether 8,075 t of retained catch and 6,480 t of processed products destined for international markets (Table 1, 4). Nearly 70% of the total retained catch was composed of the Argentine hake (41.1%) and the Argentine shortfin squid (28.6%) (Table 4). The bone fishes silver John dory, monkfish, Brazilian codling, and black grouper composed together 23% of the total retained catch.

**Table 4.—Catch in tons (t) retained by the chartered trawlers off Brazil from October 2000 to October 2003. Numbers in parentheses represent percentages of the total retained catch of each vessel. Argentine shortfin squid, *Illex argentinus*; Argentine hake, *Merluccius hubbsi*; silver John dory, *Zenopsis conchifera*; monkfish, *Lophius gastrophysus*; Brazilian codling, *Urophycis mystacea*; black grouper, *Epinephelus nigritus*; deep-sea shrimps, family Aristeidae; and other bony and cartilaginous fish.**

| Vessel | Argentine shortfin squid | Argentine hake | Silver John dory | Monkfish | Brazilian codling | Black grouper | Deep-sea shrimp | Others | Total |
|---|---|---|---|---|---|---|---|---|---|
| *Joana* | 56.9 | 47.5 | 124.9 | 19.1 | 3.7 | 0.0 | 0.0 | 17.6 | 269.7 |
| | (21.1) | (17.6) | (46.3) | (7.1) | (1.4) | (0.0) | (0.0) | (6.5) | |
| *Insung 207* | 1,830.7 | 1,657.9 | 420.1 | 178.5 | 33.5 | 0.0 | 0.0 | 329.5 | 4,450.2 |
| | (41.1) | (37.3) | (9.4) | (4.0) | (0.8) | (0.0) | (0.0) | (7.4) | |
| *Rio Bouzos Uno* | 83.9 | 348.5 | 13.7 | 19.0 | 37.1 | 0.0 | 0.0 | 22.1 | 524.3 |
| | (16.0) | (66.5) | (2.6) | (3.6) | (7.1) | (0.0) | (0.0) | (4.2) | |
| *Cipi* | 41.6 | 270.6 | 27.7 | 30.6 | 16.9 | 0.0 | 0.0 | 6.6 | 394.0 |
| | (10.6) | (68.7) | (7.0) | (7.8) | (4.3) | (0.0) | (0.0) | (1.7) | |
| *Nuevo Apenino* | 74.8 | 498.0 | 36.8 | 39.5 | 39.2 | 0.0 | 0.6 | 42.2 | 731.1 |
| | (10.2) | (68.1) | (5.0) | (5.4) | (5.4) | (0.0) | (0.1) | (5.8) | |
| *Hermanos Vaqueros* | 13.3 | 187.1 | 1.9 | 61.5 | 27.7 | 0.0 | 0.0 | 19.9 | 311.4 |
| | (4.3) | (60.1) | (0.6) | (19.8) | (8.9) | (0.0) | (0.0) | (6.4) | |
| *Emanguluko* | 118.1 | 61.0 | 37.1 | 31.4 | 3.6 | 0.0 | 0.0 | 3.8 | 255.0 |
| | (46.3) | (23.9) | (14.5) | (12.3) | (1.4) | (0.0) | (0.0) | (1.5) | |
| *Arneles* | 1.6 | 7.3 | 0.6 | 0.2 | 0.0 | 0.0 | 0.0 | 1.0 | 10.7 |
| | (14.8) | (68.8) | (5.4) | (1.8) | (0.0) | (0.0) | (0.0) | (9.2) | |
| *Costa Grande* | 86.0 | 241.3 | 11.8 | 327.7 | 13.6 | 0.0 | 41.4 | 45.5 | 767.3 |
| | (11.2) | (31.4) | (1.5) | (42.7) | (1.8) | (0.0) | (5.4) | (5.9) | |
| *Mar Maria* | 5.4 | 3.1 | 0.0 | 4.5 | 1.1 | 293.1 | 34.2 | 19.6 | 361.0 |
| | (1.5) | (0.9) | (0.0) | (1.2) | (0.3) | (81.2) | (9.5) | (5.4) | |
| Total | 2,312.3 | 3,322.3 | 674.6 | 712.0 | 176.4 | 293.1 | 76.2 | 507.8 | 8,074.6 |
| | (28.6) | (41.1) | (8.4) | (8.8) | (2.2) | (3.6) | (0.9) | (6.3) | |

Deep-sea shrimps (family Aristeidae) and other bony and cartilaginous fish composed the remaining 7.2%.

Annual production peaked at 5,000 t in 2002 when nine trawlers were operating simultaneously in Brazilian waters (Fig. 4A). The bulk of this production was composed of massive catches of Argentine hake and Argentine shortfin squid (Fig. 4B). The trawler *Insung 207* produced the largest overall catch. This trawler not only conducted the greatest number of trips during the study period but also obtained, in 2002, the largest Argentine shortfin squid catch ever recorded in Brazilian waters (1,241 t in three fishing trips in July–September 2002). In all the other years the Argentine hake was the most abundant species in the catch (Fig. 4B).

The main catch components during the study period were principally caught in the area delimited by lat. 23°S and lat. 25°S (Fig. 5A). An exception was the Argentine shortfin squid whose catches concentrated further south between lat. 26°S and lat. 30°S. Also it is worth noting that the Brazilian codling was the only retained species caught throughout the entire latitudinal range whereas the deep-sea shrimps were restricted to northernmost areas (Fig. 5A). Chartered fleet operations also obtained most of their catch in the 300–500 m depth stratum with the exception of the deep-sea shrimps that were caught in depths of 700 m on average (Fig. 5B). All species were caught throughout the 24-h period, but the Argentine shortfin squid and the Argentine hake were mostly caught during daytime whereas catches of the silver John dory and the monkfish tended to be larger between 1200 h and 2400 h (Fig. 5C).

Slope trawling off northern and northeastern Brazil had deep-sea shrimps and the black grouper as the main targets, respectively, the latter composing over 90% of retained catch. Off southeastern and southern Brazil the six most abundant components of the retained catches were initially regarded as potential targets of chartered trawlers during the studied period.

The analysis of targets in multispecies fisheries, as proposed by Biseau (1988), enabled the characterization of three types of cumulative frequency distribution curves of the catches (Fig. 6). These curves were used to define criteria for the classification of the species into three categories: incidental, target-species, and massive target species (Table 5). Following these criteria, cumulative curves built for all six species were analyzed considering all recorded tows and tows pooled by trawler, trimester, latitudinal and bathymetric strata (Table 6).

The Brazilian codling was generally classified as an incidental species (Fig. 6) for all chartered trawlers, where the species rarely contributed more than 20% of the retained catch (Table 6). The same was observed in most trimesters and in latitudinal and bathymetric strata. Exceptions to this pattern were found in tows south of lat. 29°S and during the end of 2000, when the species may have

**Table 5.—Criteria for classification of the species caught by the chartered trawlers fleet operating off Brazil into target categories adapted from Biseau (1988).**

| Species | Definition | Criteria |
|---|---|---|
| Incidental | Species not subject to directed effort but retained due to its commercial value | More that 40% of the species total retained biomass originated from tows where the species represented less than 20% (QL) of the retained biomass |
| Target species | Species subject to directed effort | Between 30 and 60% of the species total retained biomass originated from tows where the species represented more than 40% (QL) of the retained biomass |
| Massive target species | Species subject to directed effort whose distribution is extremely gregarious and that are caught in large quantities without abundant bycatch | More than 60% of the species total retained biomass originated from tows where the species represented more than 40% (QL) of the retained biomass |

been included in the role of the targets during the trawling exploratory phase (Table 6).

The monkfish was classified as a target species in general terms but such classification was not homogeneous among trawlers (Fig. 6, Table 6). Furthermore the species was incidental during most of the analyzed period, but during the second trimesters of 2001, 2002, and 2003 it oscillated between target species and massive target species. The same was observed in areas deeper than 600 m (Table 6).

The Argentine shortfin squid, the Argentine hake, the silver John dory and the deep-sea shrimps (here analyzed as one single category) were classified as massive target species which means that they constituted targets of highly directed effort and/or occurred in such dense mono-specific concentrations in nature as to contribute to the largest part of the catch obtained by each tow (Fig. 6). In all species, however, that classification was not homogeneous among trawlers (Table 6). Furthermore, the exploitation of the Argentine hake and the Argentine shortfin squid as massive targets was restricted to the period between late 2001 and early 2003, in the former species, and to the winter seasons, south of lat. 25°S and between 200–600 m depths in the latter species (Table 6). The silver John dory was classified as a massive target species in several fishing seasons, all latitudinal strata, and in areas shallower than 400 m (Table 6).

Deep-sea shrimps were a target species in the tows conducted by the trawler *Nuevo Apenino* who produced the first commercial catches of these species off southeastern Brazil. The trawlers *Costa Grande* and *Mar Maria*, on the other hand, directed their operations to these shrimps where they were classified as a massive target species (Table 6). Such conditions were observed from late 2002 onwards, as these vessels initiated their operations in Brazilian waters, north of lat. 25°S and deeper than 600 m (Table 6).

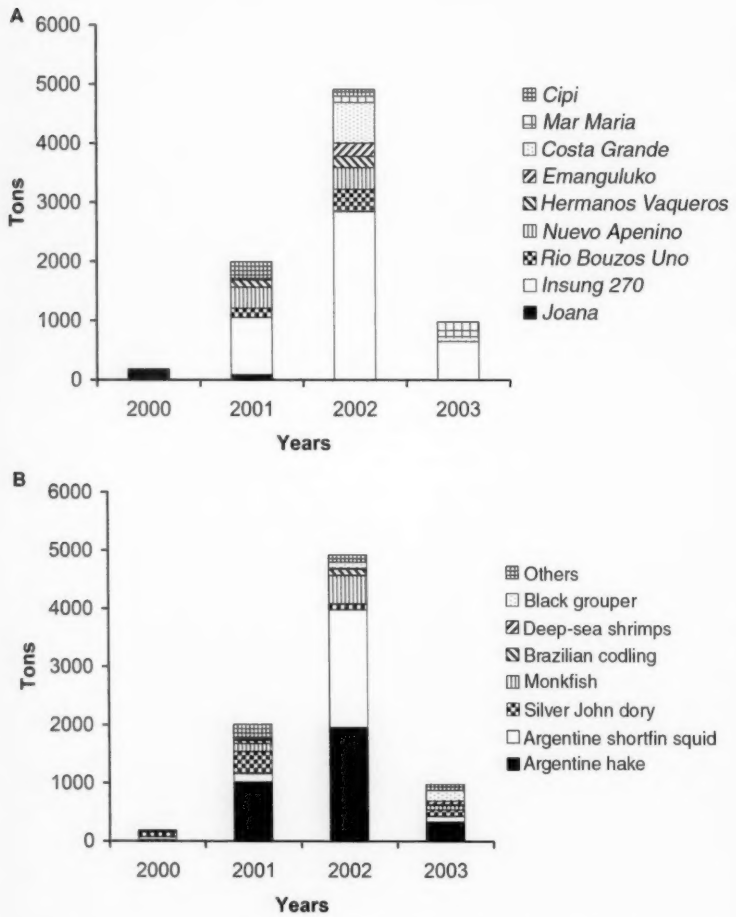



Figure 4.—Total retained catches reported by chartered trawlers off Brazil between 2000 and 2003 classified by vessel (A) and species (B).

## Catch Rates

In the southern and southeastern sectors of Brazilian coast total retained catch rates were, on average, 123,012.2 kg/trip (± 15,384.1 kg/trip SE) and 368.9 kg/h (± 11.5 kg/h SE) (Tables 7, 8). These rates increased in 2001–02 (394–489 kg/h) during the upper slope directed phase (targeting the Argentine hake and the Argentine shortfin squid) and decreased almost 60% in 2003, when the lower slope directed phase aiming at the deep-sea shrimps was established (Table 8). Mean catch rates were highest in the shallowest and southernmost strata and tended to decrease toward deep northern grounds (Fig. 7). Mean catch rates in northern and northeastern Brazil, were 39,729.6 kg/trip (± 13,033.5 kg/trip SE) and 107.2 kg/h (± 3.9 kg/h SE) (Tables 7, 8).

The Argentine hake and the Argentine shortfin squid were the most productive targets of the chartered slope trawling off Brazil reaching, on average, over 100 kg/h (Table 8). The former species was most productive in 2001 and 2002 when mean catch rates oscillated between 171.3–183.3 kg/h. In 2003 catch rates dropped sharply to nearly 30% of the previous levels. The Argentine shortfin squid, on the other hand, had one sporadic fishing episode in mid 2002 when catch rates of one particular trawler averaged nearly 200 kg/h (Table 8).

Aside from that episode, mean catch rates varied between 16 and 48 kg/h. Monkfish catch rates were also superior in 2001 and 2002, although interannual variability was not as pronounced as in the case of the Argentine hake. The silver John dory and the Brazilian codling were not permanent targets of the chartered fleet, and therefore the retained catches may not have been related with their availability on the slope fishing grounds. However, the elevated catch rates of the silver John dory between 2001 and 2003 were noticeable (Table 8). In general, all catch rates declined in 2003 except for those recorded for the deep-sea shrimps (Table 8). In essence that reflects the reduction of the chartered fleet that year and the intensification of trawling in the lower slope grounds where most of the fish and squid targets are not abundant.

The Argentine hake and Argentine shortfin squid catch rates were slightly highest at depths shallower than 200 m and tended to decrease toward deeper grounds being totally absent in areas deeper than 600 m (Fig. 7A). Latitudinally, however, both species exhibited inversed distribution patterns with Argentine hake and Argentine shortfin squid catch rates being largest in the northern and southern sectors, respectively (Fig. 7B). Whereas the monkfish catch rate distribution was relatively homogeneous in all depth and latitudinal strata, silver John dory catch was scarce in areas deeper than 400 m and in all latitudinal strata (Fig. 7). Deep-sea shrimps catch rates were only available for the lower 600 m areas of the northern sector (Fig. 7).

## Discussion

Chartered trawlers operated in the Brazilian slope following patterns in many ways similar to the ones exhibited during the development of deep-water trawling in the North Atlantic, which involved both exploratory and specialized phases in association with different trawler types (Iglesias and Paz, 1995; Charuau et al., 1995; Gordon, 2001). Off Brazil, the process was pioneered in late 2000–early 2001 by two large vessels that covered broad latitudinal

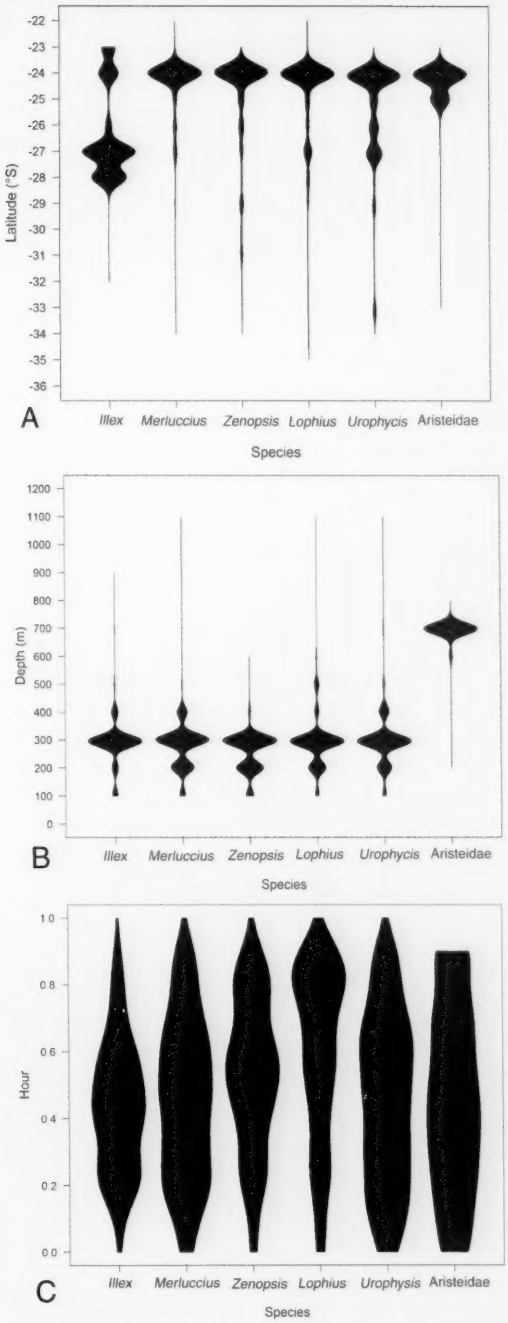



Figure 5.—Distribution of catches of Argentine shortfin squid, Argentine hake, silver John dory, monkfish, and deep-sea shrimps (family Aristeidae) off Southeastern and Southern Brazilian slope between 2000 and 2003. Area widths are proportional to the relative contribution of latitudes (A), depth (B), and decimal transformed hour of fishing (C) (e.g. 0.5 is 1200h; 0.0 is 2400h) to the total catch of each species.

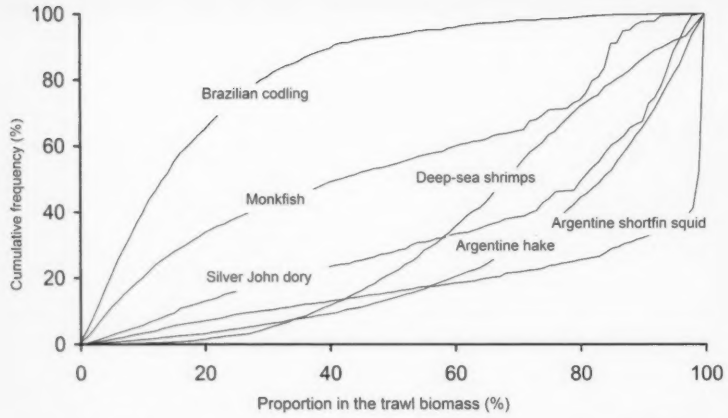



Figure 6.—Fishing target analysis of chartered trawlers on slope areas off Brazil from 2000 to 2003. Curves are cumulative frequencies of the relative contributions of the main catch components to the biomass produced by one trawl (QL).

areas and a variety of habitats. These vessels obtained some of the first profitable catches of resources previously considered as either unproductive or uneconomical, aside from delimiting their main slope fishing grounds (Perez et al., 2003; Haimovici, 2007).

This exploratory phase was shortly followed by the entry of Spanish trawlers highly focused on Argentine hake production in the southeastern sector of the Brazilian slope. Previously operating off northwest Africa, such vessels were smaller, highly efficient, and able not only to fully exploit the hake concentrations 300–400 m deep but also to occasionally explore the deep slope for new opportunities. By the end of 2002, as international markets for hake caught off Brazil became no longer favorable, most vessels abandoned Brazilian waters.

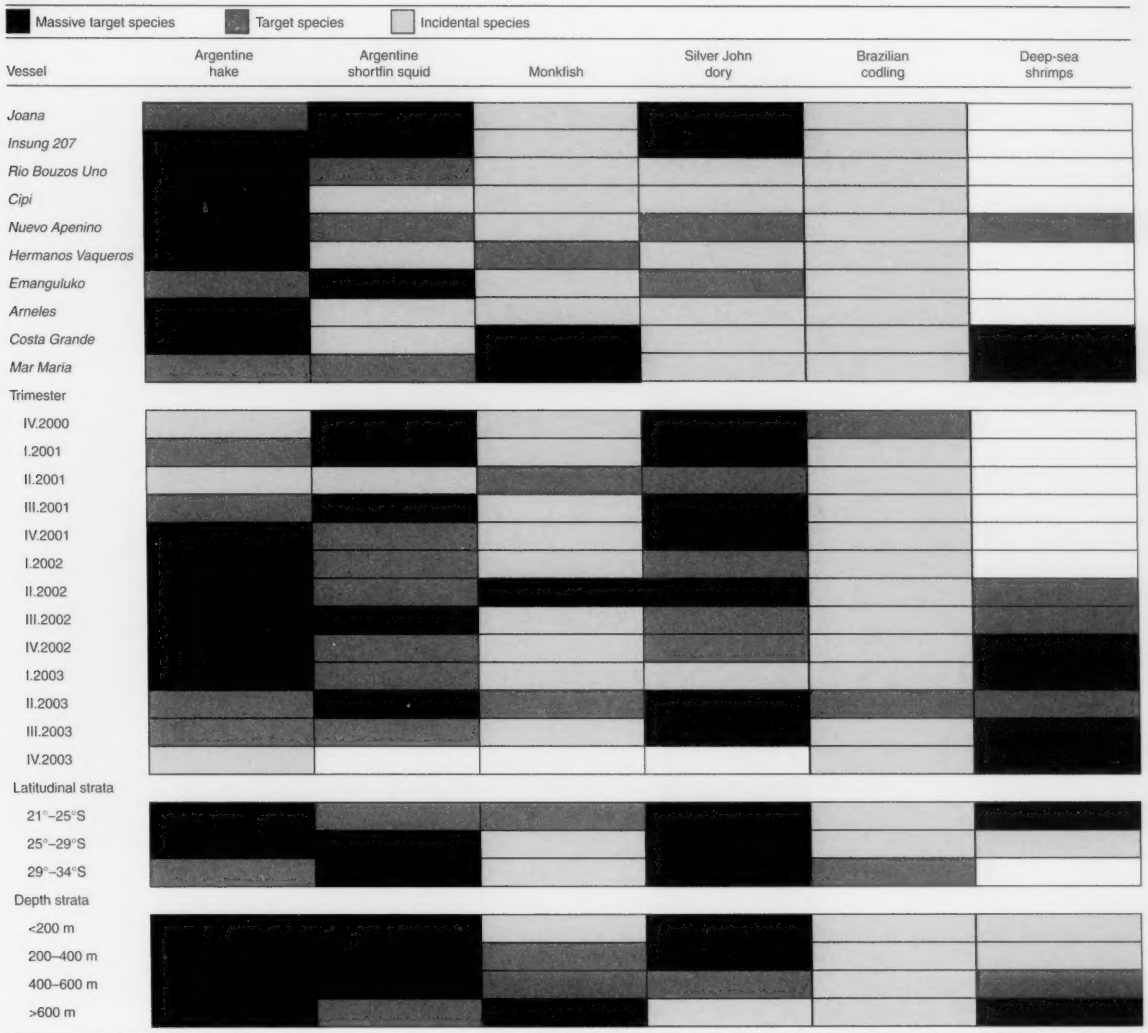
In association with the end of the directed phase, however, a) a "national" trawl fishery consolidated on the upper slope grounds off southeastern Brazil aiming at hake and other species mostly for the domestic market (Perez and Pezzuto, 2006), and b) a new phase directed towards valuable aristeid shrimps began from the subsequent operations of two remaining Spanish trawlers. This justified the continuation of the chartering program and the onset of a new lower slope trawl fishing phase (Pezzuto et al., 2006b).

In northern and northeastern Brazilian waters, chartered trawling led to less promising perspectives. First, another potential fishing ground for aristeid shrimps was detected off the northern State of Amapá, possibly associated with stocks already exploited in the French Guiana EEZ (Guéguen, 2000; Pezzuto et al., 2006b). Unlike the trawlers in the neighboring country, these grounds have not attracted the Brazilian trawl fleet that is strongly focused on the coastal pink shrimp, *Farfantepenaeus subtilis*, production (Aragão et al., 2004). As for chartered trawlers, the area was not considered a priority due to operational difficulties, as imposed by strong bottom currents and deep fine sediment layers. Secondly, the chartered fleet produced a brief and unprecedented trawl fishing episode on the flat tops of some seamounts off northeastern Brazil, which exploited to exhaustion dense concentrations of the black grouper. Both scientists and fishing authorities reaction to the analysis of this episode was to recommend the closure of these seamounts for trawl fishing and include them on the list of potential Marine Protected Areas of the Brazilian coast (Anonymous, 2006)

Brazilian slope trawling until 2003 concentrated on the so-called "permanent residents of the upper 400 m" (Gordon et al., 1995; Gordon, 2005) composed of species more closely related to shelf dwellers than true deep-sea forms (Merret and Haedrich, 1997). Off southeastern and southern Brazil, these targets were amongst the dominant species of the upper slope area (100–500 m) as shown by trawl surveys conducted in 2001–02 (Haimovici et al., 2006b). These surveys also showed the silver John dory, Argentine hake, Brazilian codling, monkfish, and Argentine shortfin squid particularly concentrated on the 300–500 m depth stratum where both chartered and national trawlers overlapped and obtained their most productive catches between 2000 and 2003 (Perez and Pezzuto, 2006). Latitudinally, catch patterns of the chartered fleet also coincided with those shown by the national trawlers and the trawl surveys including, for example, the well-known concentration of Argentine hake and the gulf hake in the northern and southern extremes of the fishing area respectively (Perez and Pezzuto, 2006; Haimovici et al., 2006b). Whereas landings composition corroborated such spatial exploration pattern, existing differences between national and chartered fleets could be related, however, to the national/international market preferences aimed by these fleets respectively (Perez et al., 2002a; Perez et al., 2003; Perez and Pezzuto, 2006). Thus the abundant gulf hake has been a major target of national but not chartered trawlers, and the silver John dory and Argentine squid has been mostly retained (and exported) by chartered vessels. These differences further implied in particular (although not yet empirically addressed) discard practices involving the above mentioned and other abundant slope species including beardfish, *Polimixia lowei*; Splendid alfonsino, *Beryx splendens; Helicolenus lahillei*; and Marini's grenadier, *Caelorinchus marinii* (Haimovici et al., 2006b).

A particular scenario emerged from the establishment of the aristeid shrimp-directed lower slope fishery. Trawling operations in this area have been highly restricted to the most productive 700–800 m depth range and produced significant catches of the deep-sea

**Table 6.—Analysis of the targets of the chartered trawler fleet operating off Brazil from October 2000 to October 2003 according to criteria defined in Table 5. White areas refer to species not present in the catches.**




crabs, *Chaceon ramosae* (Pezzuto et al., 2006b) as well as a high diversity of truly deep-sea fin-fish (families Synaphobranchidae, Macrouridae, Trachichthyidae, Berycidae, Astronesthidae, Oreosomatidae, Ipnopidae, Alepocephalidae, Ophidiidae and others), elasmobranches (families Rajidae, Scyliorhinidae), holocephalids (family Chimaeridae), and cephalopods (family Histioteuthidae, subfamily Bathypolipodinae).[1] Hitherto none of these bycatch species (some of them commercially exploited elsewhere) have been identified as potential fishing targets, a consequence of either the high profitability of aristeid shrimp catches or inexistent (or still undetected) specific productive grounds. Whereas the next deep-water trawling phase off the Brazilian coast is uncertain, the abundant and diverse by-catch produced by deep-water shrimp trawling, as also described for similar fisheries worldwide (Sartor et al., 2003; D'Onghia et al., 2003), may be a critical aspect to be considered for the future development of this new Brazilian fishery.

Bottom trawling is a traditional fishing practice in Brazil that has sustained a significant proportion of the country's demersal catches in the past 40 years (Haimovici et al., 2006a; Valentini and Pezzuto, 2006). This practice devel-

[1]Perez, J. A. A. Centro de Ciências Tecnológicas da Terra e do Mar – CTTMar, Universidade do Vale do Itajaí–UNIVALI, Cx. Postal 360, Itajaí, Santa Catarina, Brazil CEP 88302-202. Personal commun., 2008.

oped as a large-scale industry, after the technological influence of a process of chartering and importing double-rig trawlers from the Gulf of Mexico in the mid 1960's (Valentini et al., 1991). From 2000 onwards, the chartering of foreign vessels reappeared as a mechanism to induce the expansion of such industry into deep-sea areas, a process that involves new paradigms on fishing, processing, and commercializing (Perez et al., 2001; Perez et al., 2003). Unlike the introduced bottom gillnets for monkfish fishing and pots for deep-sea crabs (Wahrlich et al., 2005; Pezzuto et al., 2006a), slope trawling could rapidly become a concrete trend of national fishing owing to the already available fleet and the lower costs involved in setting those new paradigms. In fact, southeastern and southern upper slope occupation by both national and foreign trawlers was virtually simultaneous, the latter being regarded by the former more like unfair competitors than models. The analysis of data generated extensively by observers on board chartered trawlers, however, allowed some important distinctions to be made about the factual role of chartering to the development of slope trawling off Brazil.

Chartered vessels, in comparison with national ones, were larger, powered by stronger engines and with faster winches, could spend a long time at sea and had crews experienced in operations over slope grounds elsewhere in the Atlantic. As explorers, these vessels were able to cover a vast area between the two extremes of the country's EEZ, from 100 to 1,000 m, accomplishing in 2 years more than any research vessel or national trawler had in decades. However, these vessels were market-oriented with elevated profit demands, which made them quickly turn from exploration to exploitation particularly focused on Argentine hake and aristeid shrimps concentrations in southeastern Brazil. Technologically limited, national trawlers, traditionally operating on the shelf and shelf break in that region, were able to expand to the upper slope and compete with foreign trawlers for hake but not for the valuable deep-sea shrimps on deeper areas. In the latter case fishing technology possibly justified chartering, as national trawlers could not easily assess these grounds. In the former case, however, national exploitation of Argentine hake prevailed, possibly because double-rig trawlers were more numerous, efficient, and favored by a more stable and less competitive domestic market (Perez and Pezzuto, 2006).

Another relevant aspect is concerned with the impacts the foreign trawl fleet could have made on slope resources, both individually and in addition to the ones produced by national trawlers. Recent analysis has indicated that annual Argentine hake landings

**Table 7.—Total retained catch rates (kg/trip) obtained by the chartered trawl fishery on slope grounds off Brazil between 2000 and 2003. The number of trips is presented in the first row followed by the mean catch rate (± SE) and the maximum value in parentheses. SE–S, southeastern and southern sectors; N–NE, northern and northeastern sectors.**

| Year | SE–S | N–NE |
|---|---|---|
| 2000 | 2<br>62,488.8 –120,877.4 | |
| 2001 | 16<br>124,039.5 ± 20,625.5<br>(300,980.6) | |
| 2002 | 33<br>145,540.7 ± 25,607.3<br>(516,508.2) | 3<br>38,624.8 ± 15,065.3<br>(55,035.0) |
| 2003 | 11<br>70,689.2 ± 24,221.2<br>(257,104.2) | 5<br>40,392.6 ± 20,180.8<br>(92,156.6) |
| Total | 62<br>123,012.2 ± 15,384.1<br>(516,508.2) | 8<br>39,729.6 ± 13,033.5<br>(92,156.6) |

**Table 8.—Total retained catch rates (kg/h) of the main fishing targets obtained by the chartered trawl fishery on slope grounds off Southeastern–Southern and Northeastern–Northern Brazil between 2000 and 2003. The number of tows is presented in the first row followed by the mean catch rate (± SE) and the maximum value in parentheses.**

| Species | 2000 | 2001 | 2002 | 2003 | Total |
|---|---|---|---|---|---|
| Southeast–South | | | | | |
| Argentine hake | 224 | 1,955 | 4,044 | 2,736 | 8,997 |
| | 20.0 ± 4.2 | 183.3 ± 8.3 | 171.3 ± 7.9 | 58.0 ± 4.7 | 135.0 ± 4.3 |
| | (497.2) | (6,232.9) | (9,978.0) | (3,601.0) | (9,978.0) |
| Argentine shortfin squid | 224 | 1,955 | 4,046 | 2,736 | 8,999 |
| | 48.2 ± 14.8 | 27.3 ± 2.9 | 199.4 ± 19.1 | 16.0 ± 1.8 | 101.6 ± 8.7 |
| | (1,992.9) | (2,473.0) | (48,750.0) | (2,545.9) | (48,750.0) |
| Silver John dory | 224 | 1,955 | 4,046 | 2,736 | 8,999 |
| | 105.7 ± 18.8 | 110.2 ± 9.7 | 340.4 ± 8.9 | 25.6 ± 4.5 | 40.7 ± 2.6 |
| | (1,944.9) | (7,634.7) | (10,765.8) | (8,570.0) | (10,765.8) |
| Monkfish | 224 | 1,955 | 4,046 | 2,736 | 8,999 |
| | 12.5 ± 1.9 | 27.7 ± 1.1 | 29.3 ± 2.7 | 11.9 ± 1.0 | 23.1 ± 1.2 |
| | (165.9) | (859.3) | (2,914.2) | (336.0) | (2,914.2) |
| Brazilian codling | 224 | 1,955 | 4,046 | 2,736 | 8,999 |
| | 5.2 ± 2.1 | 12.0 ± 0.6 | 9.6 ± 0.4 | 2.6 ± 0.3 | 7.8 ± 0.2 |
| | (386.9) | (805.4) | (952.4) | (656.0) | (952.4) |
| Deep-sea shrimp | | | 4,046 | 2,736 | 8,999 |
| | | | 0.9 ± 0.1 | 22.6 ± 1.3 | 2.0 ± 0.1 |
| | | | (60.0) | (695.2) | (60.0) |
| Total | 224 | 1,952 | 3,545 | 2,134 | 7,893 |
| | 183.2 ± 25.1 | 394.5 ± 13.6 | 489.4 ± 23.6 | 159.9 ± 8.9 | 368.9 ± 11.5 |
| | (2,145.0) | (7,736.0) | (48,750.0) | (6,837.0) | (48,750.0) |
| Northeast–North | | | | | |
| Black grouper | | | 497 | 601 | 1,089 |
| | | | 74.8 ± 5.9 | 102.8 ± 4.9 | 90.1 ± 3.8 |
| | | | (1,280.0) | (695.2) | (1,280.0) |
| Deep-sea shrimp | | | 497 | 601 | 1,089 |
| | | | 0.47 ± 0.07 | 0.03 ± 0.02 | 0.23 ± 0.03 |
| | | | (12.2) | (5.3) | (12.2) |
| Total | | | 497 | 601 | 1,089 |
| | | | 86.4 ± 6.1 | 124.4 ± 4.9 | 107.2 ± 3.9 |
| | | | (1,280.0) | (820.0) | (1,280.0) |

surpassed, between 2001 and 2003, the total recommended catch (2,215 t) and total biomass decreased nearly 50% from 2003 onwards (Anonymous, 2007). Chartered trawlers contributed to 38.4% (1,018.3 t) and 52.7% (1,952.9 t) of the total landings in 2001 and 2002, respectively. In the following year, total catch was maintained at the 3,000 t level, nearly 90% being produced by national vessel operations. Considering that over 160–170 national trawlers contributed annually to those catches between 2001 and 2003 in contrast to six chartered units, it is evident that the latter represented a major impact on the hake stock, and their coexistence with the national fleet would only have reduced the species abundance to more critical levels (Perez and Pezzuto, 2006; Anonymous, 2007). Similar scenarios could be described for the monkfish and the Brazilian codling, although both species were not major targets of trawlers possibly being avoided by the net arrangement in the former case (Perez et al., 2002a) or by exploiting a geographic area where the latter species is not particularly abundant (Haimovici et al., 2006b). Finally, deep-sea shrimp exploitation by chartered trawlers has been characterized by a concentration of effort on relatively restricted areas of the slope where nearly 80% abundance reductions have been estimated between 2003 and 2004 (Pezzuto et al., 2006b; Anonymous, 2007). Whereas complete assessments are still required, it is evident that such valuable resources will accommodate only a few highly controlled vessels (Anonymous, 2007).

In summary, the recent Brazilian chartering program has proven to be an efficient instrument to both explore and exploit deep-sea demersal resources of the country's EEZ. Because of the fragility and generally limited potential yields of these resources (Perez, 2006), however, eventual benefits produced by chartered trawler operations to the national industry can be rapidly cancelled out by important abundance reductions as generated by the intense removals required to match these trawlers' profit demands. Chartering trawlers for deep-water fishing development off Brazil seems no longer viable unless for specific short-term exploratory initiatives in areas deeper than 1,000 m within the country's EEZ or in international waters. Even so this process must be ruled by precaution, intense observation, and control.

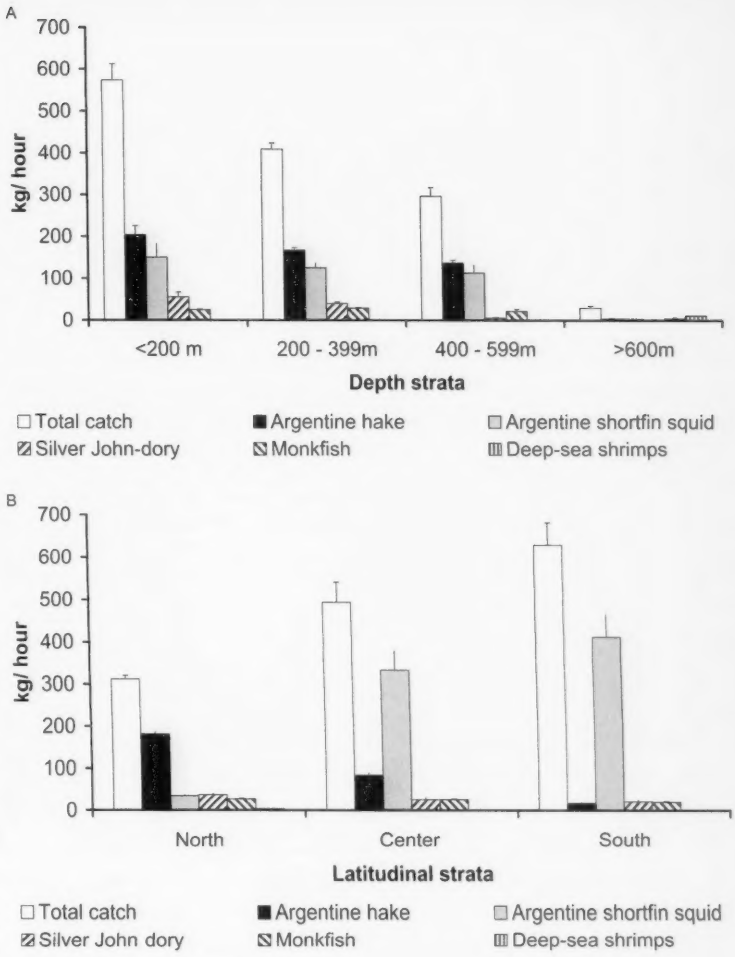



Figure 7.—Catch rate (kg/h) variability of the main components of the catches produced by chartered trawlers off Brazil from 2000 to 2003. A. Depth strata; B. Latitudinal strata (North: north of lat. 25°S; Center: lat. 25°–lat. 29°S; South: south of lat. 29°S). Bars represent mean values. Vertical lines represent one standard error.


## Acknowledgments

The authors are indebted to all members of the Chartered Fleet Observers Program for their hard work and the quality of collected data. We also thank vessel owners, captains, and crew members of all monitored vessels for the support and good will during the long fishing trips. Rodrigo Claudino dos Santos and Rodrigo Dallagnolo contributed with maps and figures. The Department of Fishery and Aquaculture, Ministry of Agriculture and the Special Secretariat of Aquaculture and Fisheries (Brazilian Government) provided funds for this study through a series of scientific cooperation programs with Vale do Itajaí University (MA/ SARC/ 03/ 2000;

MAPA/ SARC/ DPA/ 03/ 2001; MAPA/ SARC/ DENACOOP/ 176/ 2002; SEAP/ PR/ 001/ 2003; SEAP/ PR/ 078/ 2004; SEAP/ PR/ 064/ 2005).

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# Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

### The Manuscript

Submission of a manuscript to the *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed double-spaced throughout and submitted with two duplicate copies. The complete manuscript normally includes a title page, a short abstract, text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

### Abstract and Headings

Keep titles, headings, subheadings, and the abstract short and clear. Because abstracts are circulated by abstracting agencies, it is important that they represent the research clearly and concisely. Headings within each section must be short, reflect a logical sequence, and follow the rules of multiple subdivision (i.e. there can be no subdivision without at least two items).

### Style

The entire text should be intelligible to interdisciplinary readers; therefore, all acronyms, abbreviations, and technical terms should be spelled out the first time they are mentioned. The scientific names of species must be written out the first time they are mentioned; subsequent mention of scientific names may be abbreviated. Follow the U.S. Government Printing Office Style Manual (1984 ed.) and the CBE Style Manual (5th ed.) for editorial style, and the most current issue of the American Fisheries Society's Common and Scientific Names of Fishes from the United States and Canada for fish nomenclature. Only journal titles, scientific names (genera and species), and vessel names should be italicized. Dates should be written as follows: 11 Nov. 1991. Measurements should be expressed in metric units, e.g. metric tons as t; other equivalent units may also be listed in parenthesis. Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. The numeral one (1) should be typed as a one, not as a lowercase el (l). Write out the numbers zero through nine unless they form part of measurement units (e.g. nine fish but 9 mm).

### Footnotes

Footnotes should not be embedded within the text document. They must be numbered with Arabic numerals and typed on a separate sheet of paper. Footnote all personal communications, listing the name, affiliation, and address of the communicator and date of communication. Unpublished data and unpublished manuscripts should include the title, author, pagination of the manuscript or report, and the address where it is on file. Authors are advised to avoid references to nonstandard (gray) literature, such as internal, project, processed, or administrative reports, wherever possible. Where these references are used, please include whether they are available from NTIS (National Technical Information Service) or from some other public depository.

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Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted.

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